

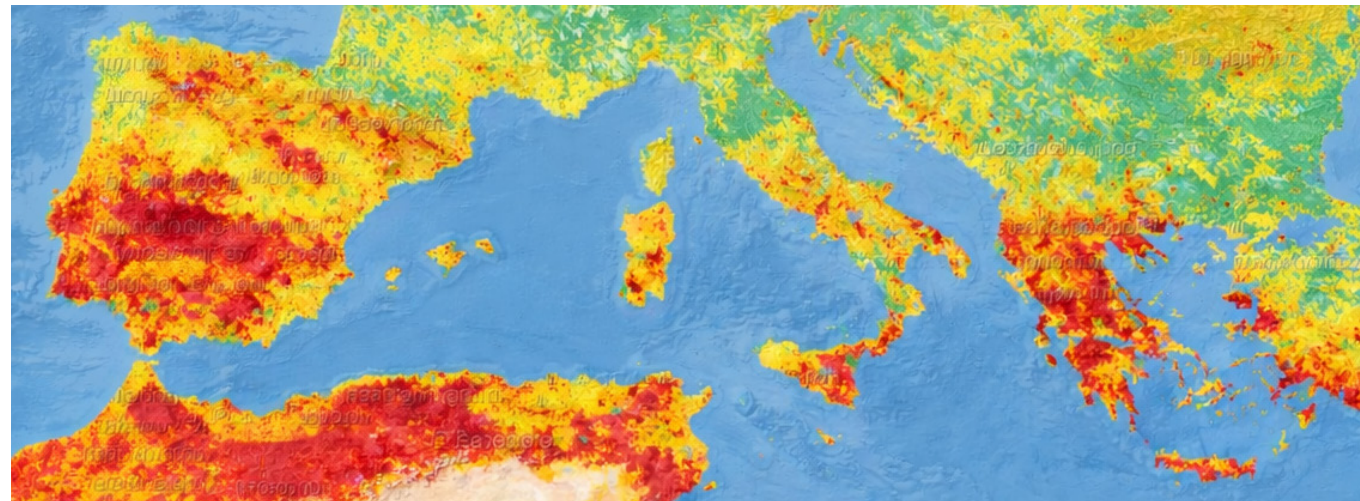
A Climate-Resilient Modular System Integrating Water Infrastructure and Earthen Construction in Mediterranean Coastal Settlements

Towards a resilient mediteranean future

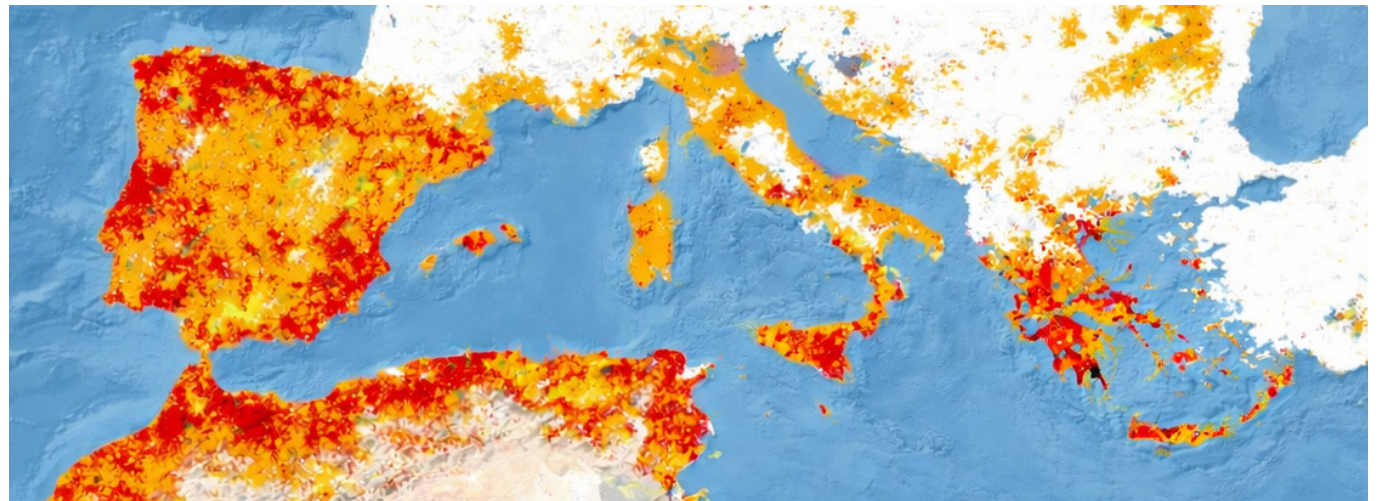
Almeria case



Wildfire risk



Drought and water shortage risk

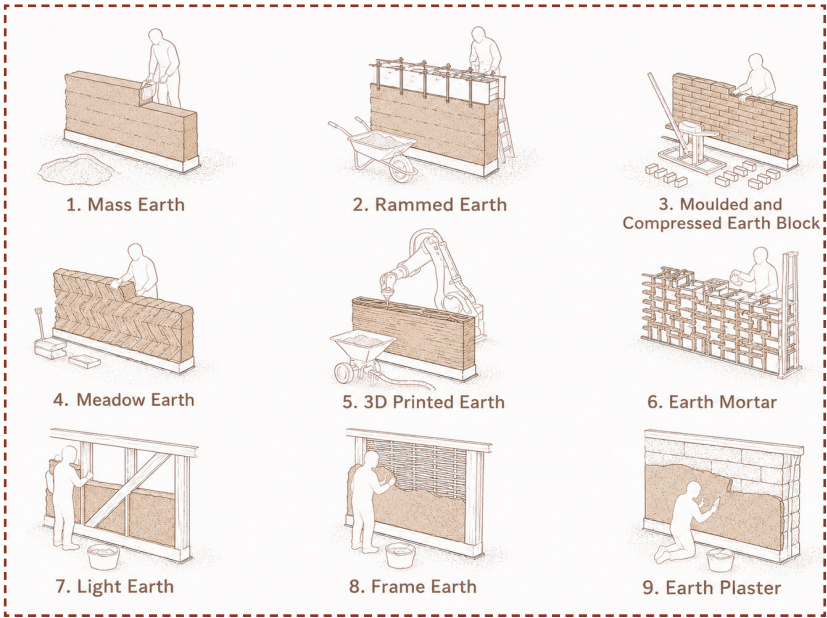


How can a place-responsive modular architectural system, grounded in earthen materiality and layered system design, enhance climate resilience in Mediterranean coastal settlements facing water scarcity and wildfire risk?

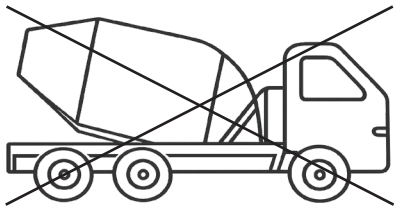
challenges

wildfire
risk

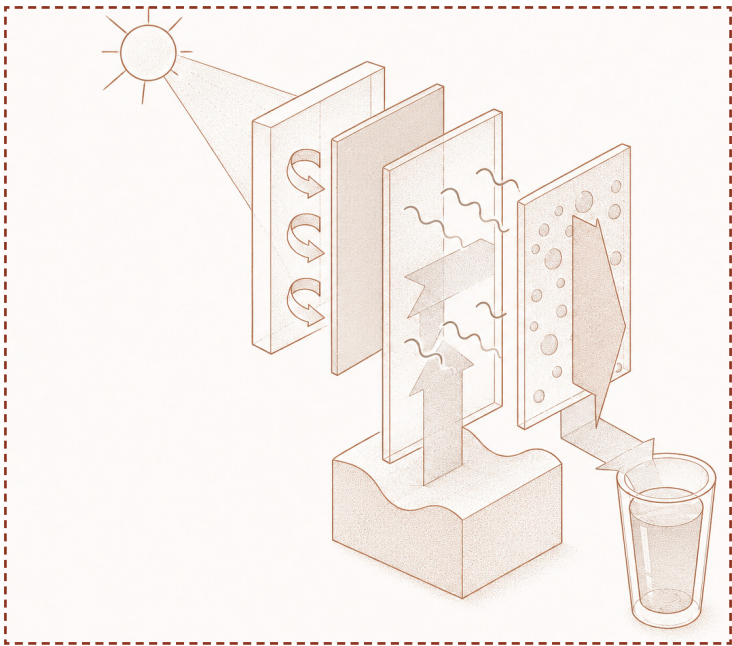
freshwater
scarcity



Earthen construction systems



Locally sourced
materials



Sea water desalination-
purification

climate resilient machine



methodology

methodology

problem



research



site



system



cluster



house

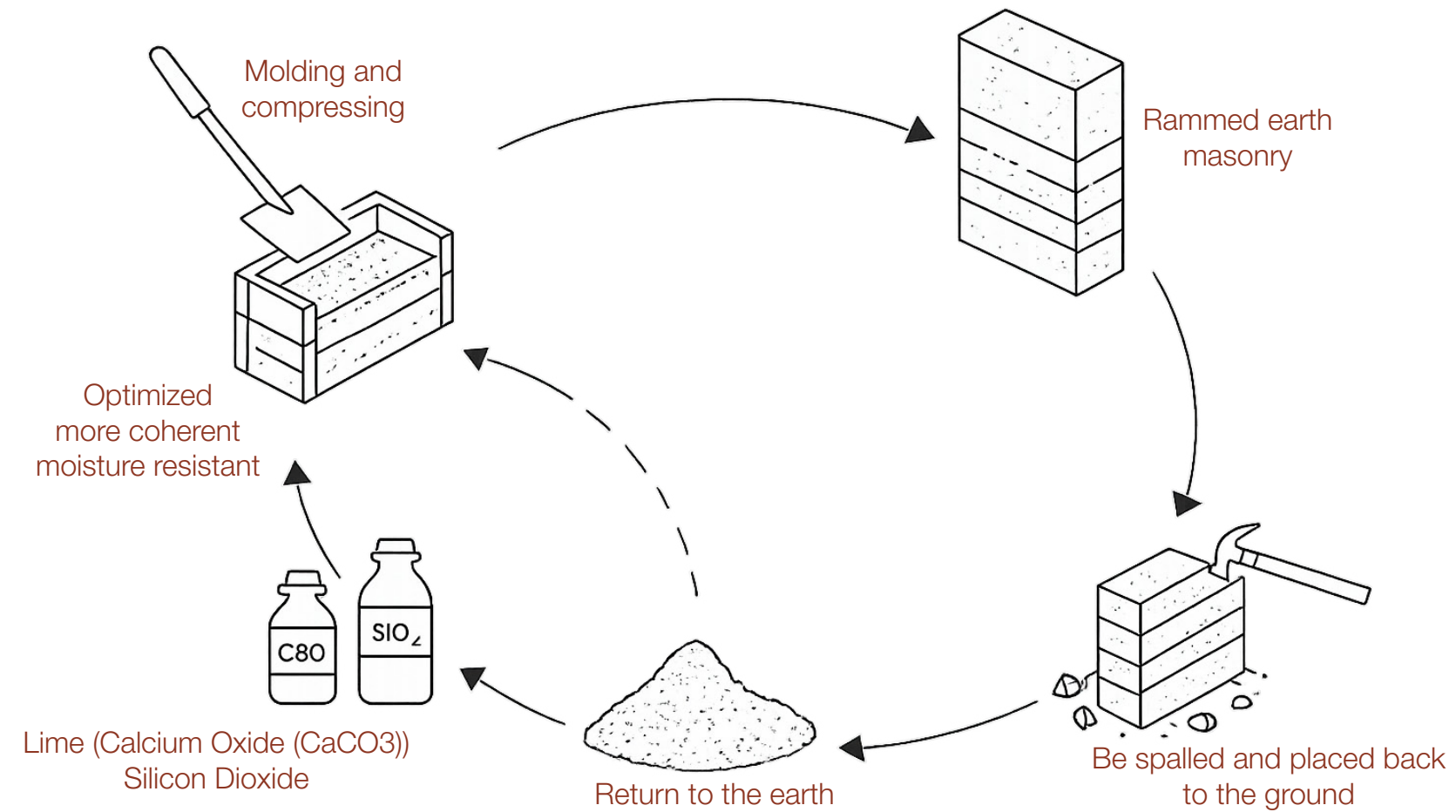


construction

Material study

Earthen Materials		Structural capacity	Fire behaviour	Moisture resistance	Thermal performance	Construction logic	Optimization Potential	Main Limitations
Adobe			Non-combustible		Very high thermal mass	Modular masonry	High – lime and pozzolans improve strength and durability	Vulnerable to rain; requires stabilization and protection
Cob block			Non-combustible		High thermal mass	Hand-placed	Moderate – fiber and lime improve cohesion	Labor-intensive; limited standardization
Compressed earth blocks			Non-combustible		High thermal mass	Industrialized masonry	Very high – lime/ pozzolans improve strength & durability	Requires mechanical pressing
Rammed earth			Non-combustible		Very high thermal mass	Formwork-based	Very high – lime/ pozzolans enhance resistance	Construction skill and formwork needed
Light clay			Non-combustible		Excellent hygro-thermal regulation	Infill panels	Moderate – lime stabilization possible	Structural dependence on frame
Hempcrete			Low flame spread		Excellent insulation	Cast-in-place	Moderate – mineral binders essential	Not structural

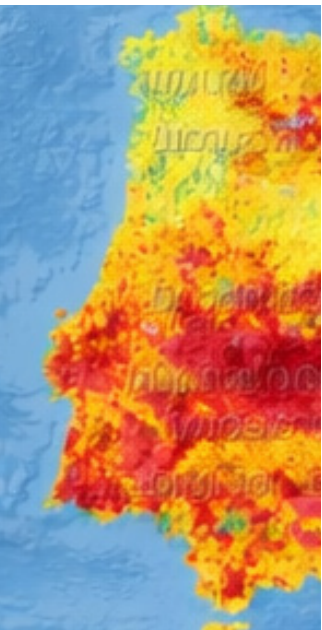
Material optimization for different applications of rammed earth



Common characteristics of potential sites

Problems and materiality

Portugal

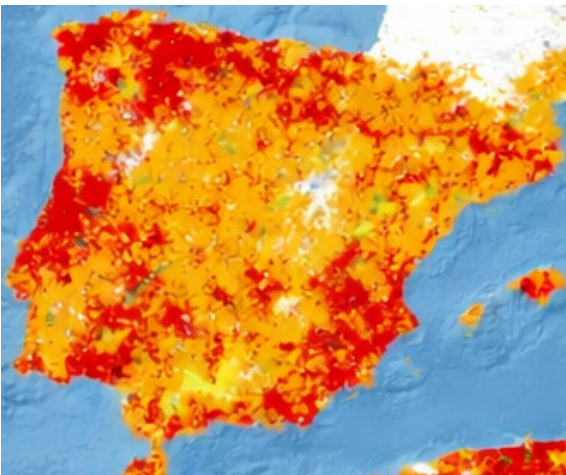


Wildfire risk

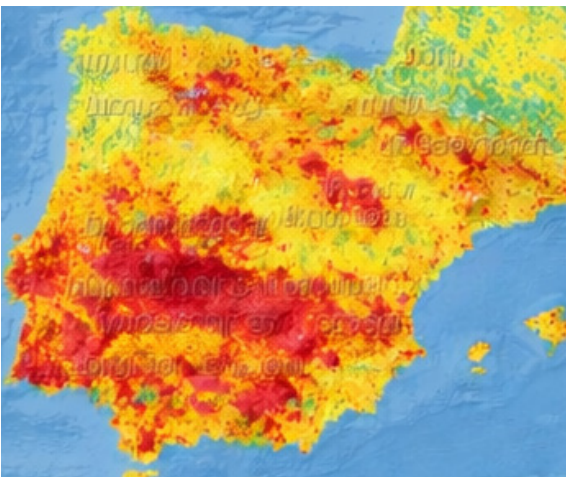


Drought risk

Spain

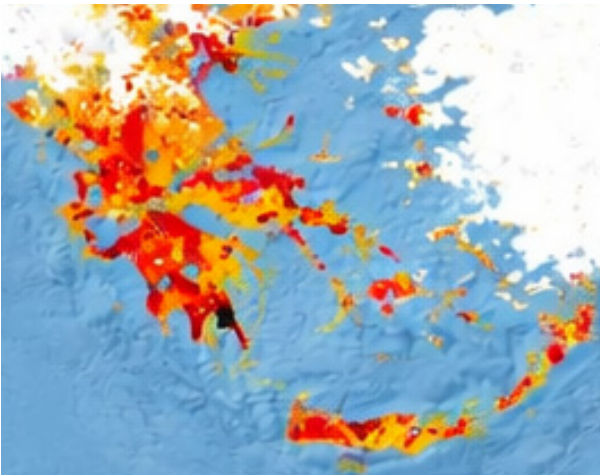


Drought risk

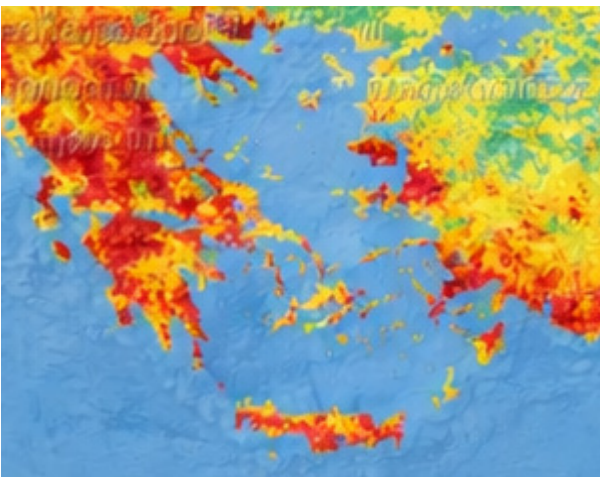


Wildfire risk

Greece



Drought risk

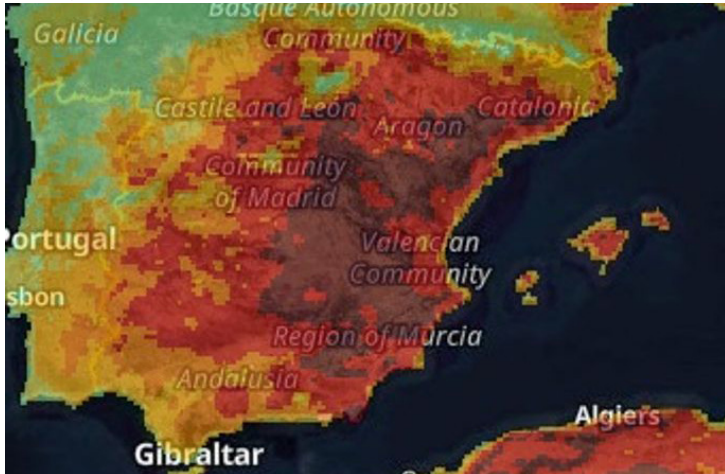


Wildfire risk

Aspect			
Climate	Hotter summers, drought	Extreme heat, desertification	Heat waves, drought
Water stress	Seasonal scarcity	Structural scarcity	Increasing scarcity
Wildfire risk	Very high	Very high	Very high
Material tradition	Clay, lime, pozzolana	Clay, adobe, lime	Clay, pozzolana
Settlement pattern	Coastal + rural	Coastal + inland	Coastal + island



Drought risk

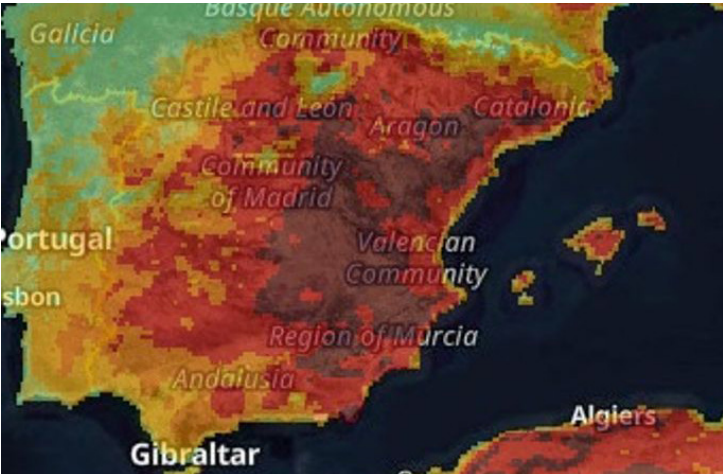


Wildfire risk

Aspect	
Climate	Extreme heat, desertification
Water stress	Structural scarcity
Wildfire risk	Very high
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Settlement pattern	Coastal + inland



Drought risk

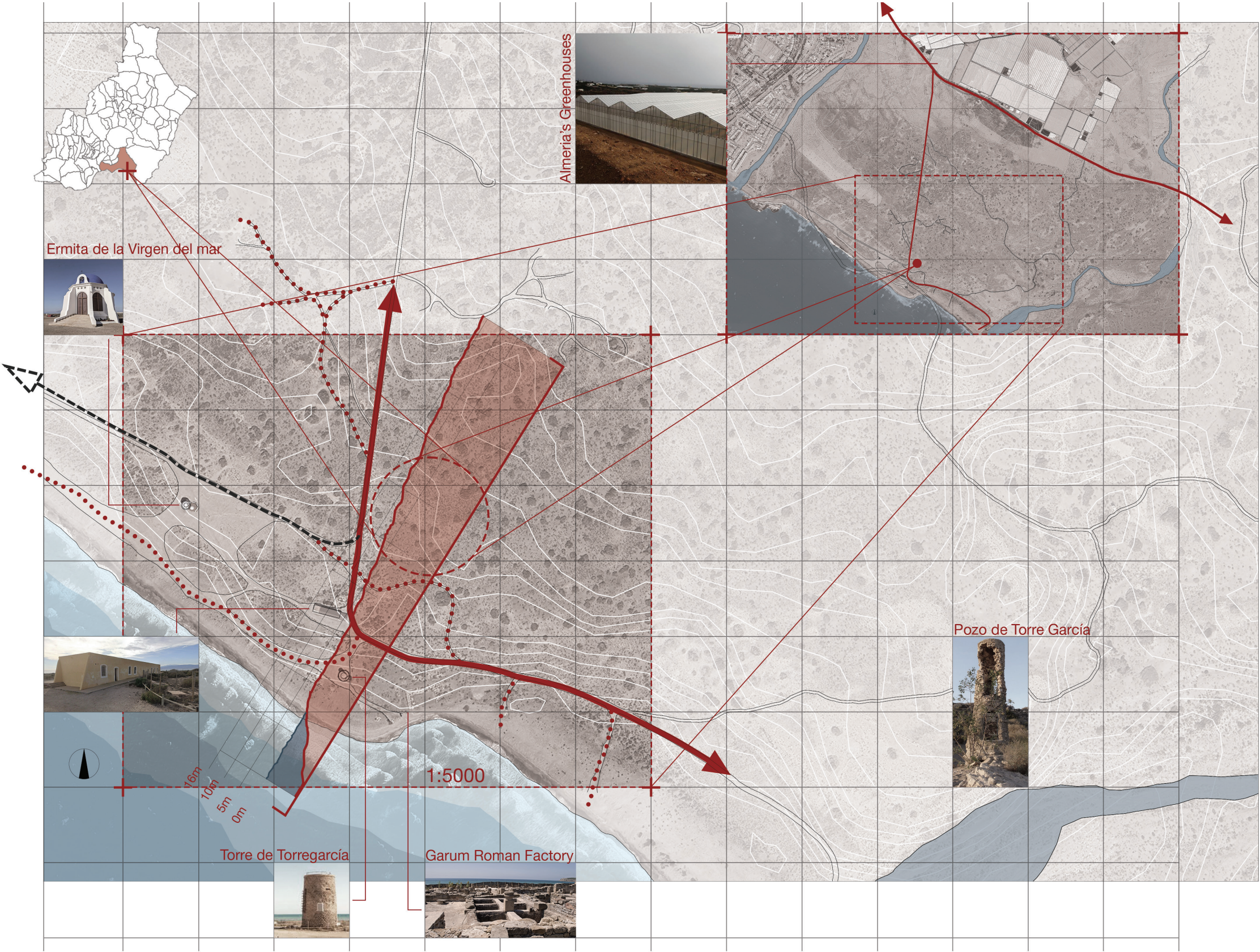


Wildfire risk

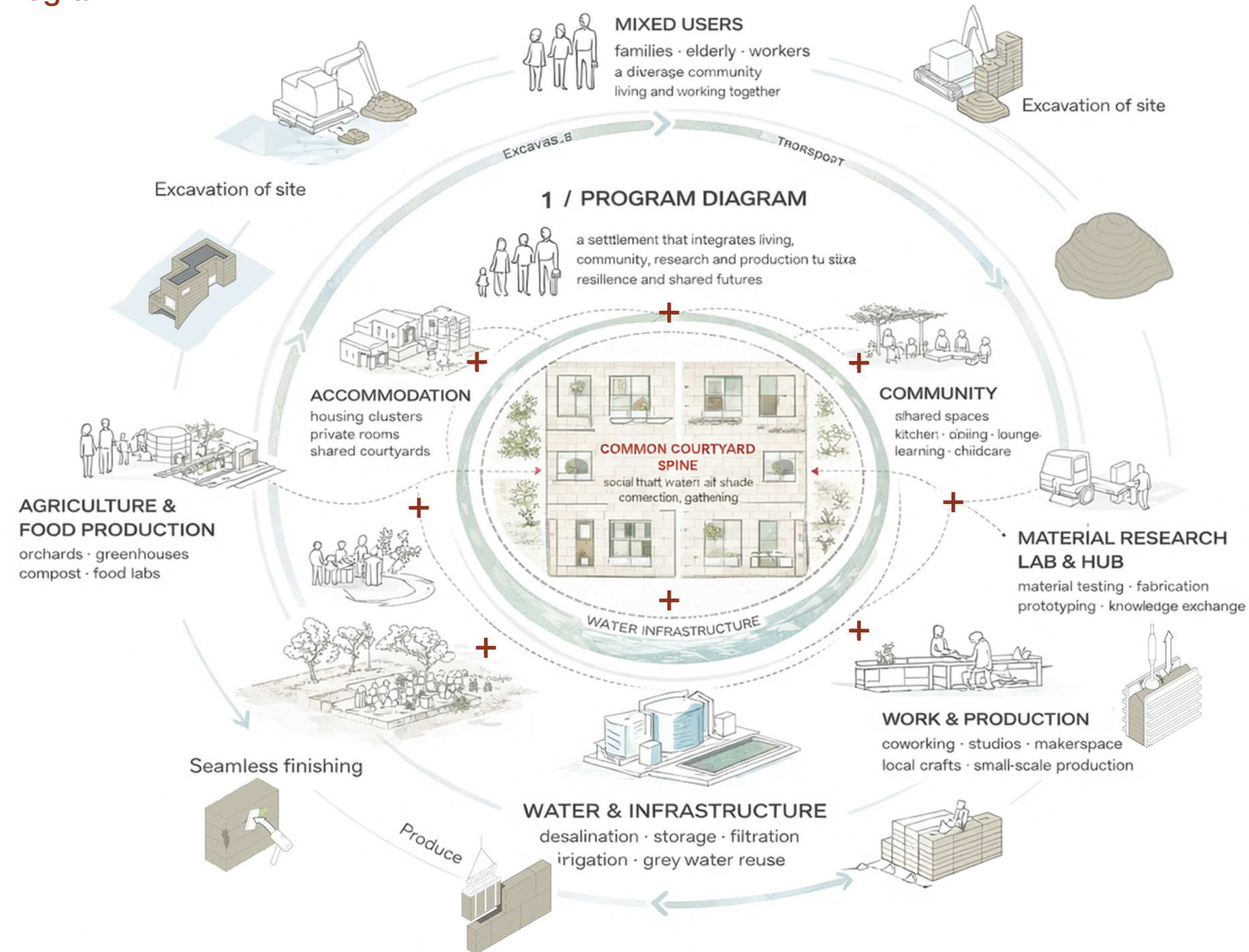
Aspect	
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Settlement pattern	Coastal + inland

Case study of the research
Almeria, Spain

Cabo da Gata
Almeria



Program



ability of a community to
**produce, maintain, adapt, and
repair its own built environment**

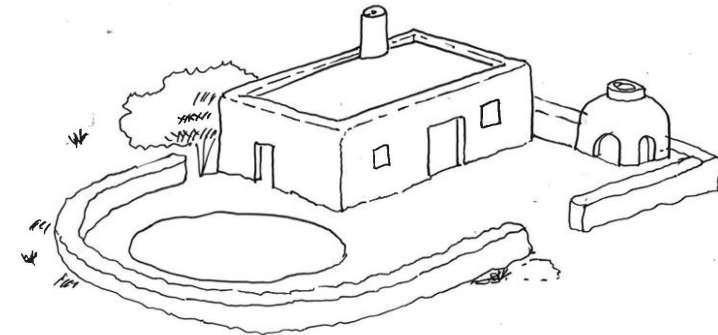
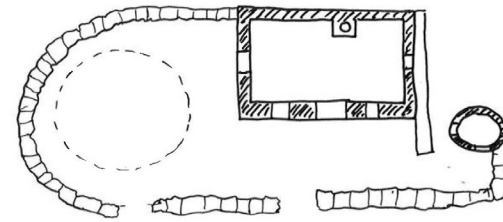
what already exists there?

Andalusian landscape



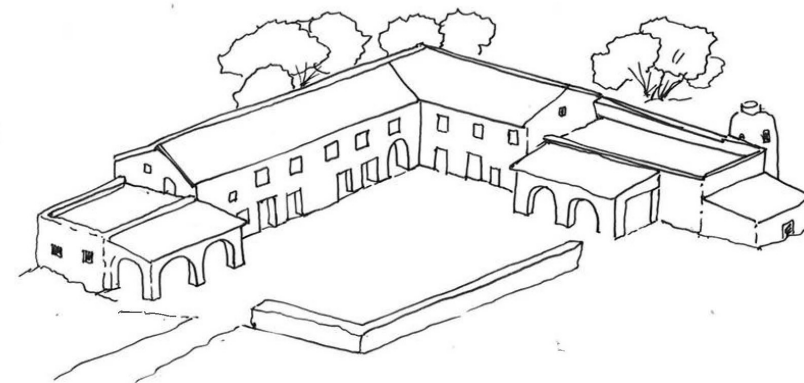
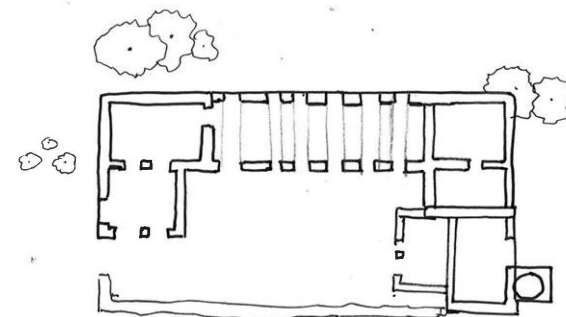
Vernacular architecture

Type 1 — Compact Cortijos



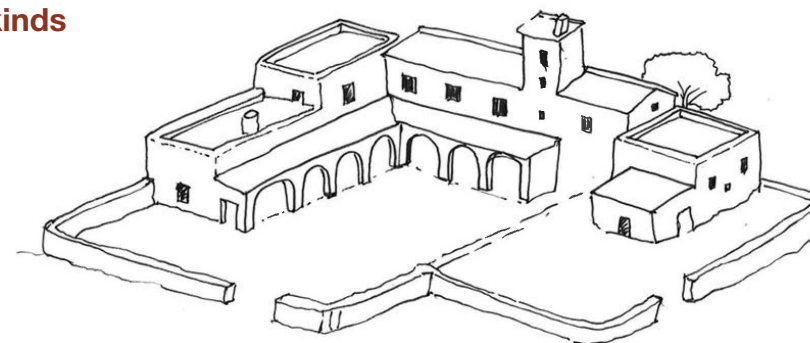
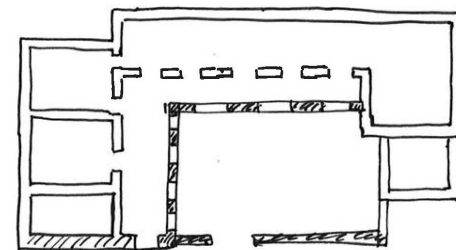
- best thermal comfort | stable int. temperature
- heat mitigation during summer
- balance / flexibility in functional programs

Type 2 — Medium Agricultural Cortijos



- functional capacity
- flexibility | expandability
- vertical spatial organization | air buffer between floors
- possibly more facilities of different kinds

Type 3 — Large Cortijo Complexes



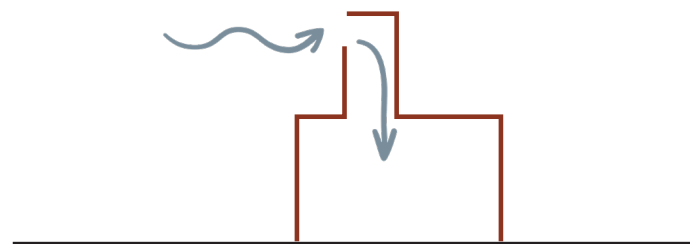
Resilience of the past

Passive cooling principles

Buffer zones- shadings



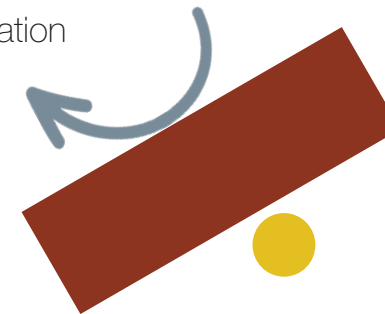
Wind catcher



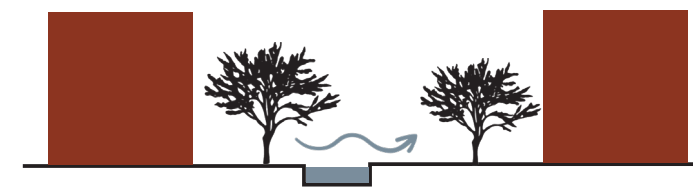
Heat exchange through ventilation n'evaporation



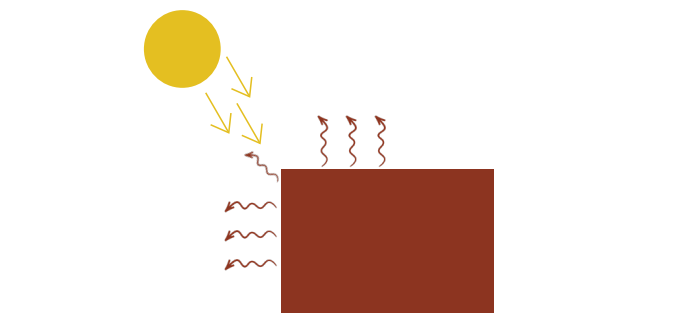
Orientation



Courtyards| water bodies| cross ventilation

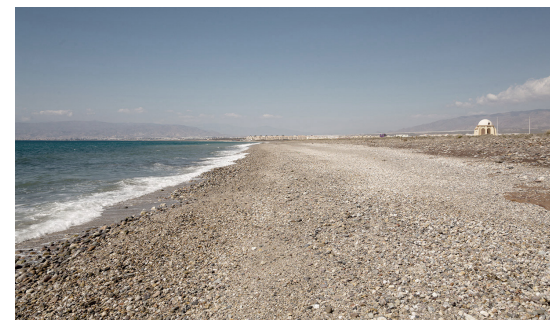
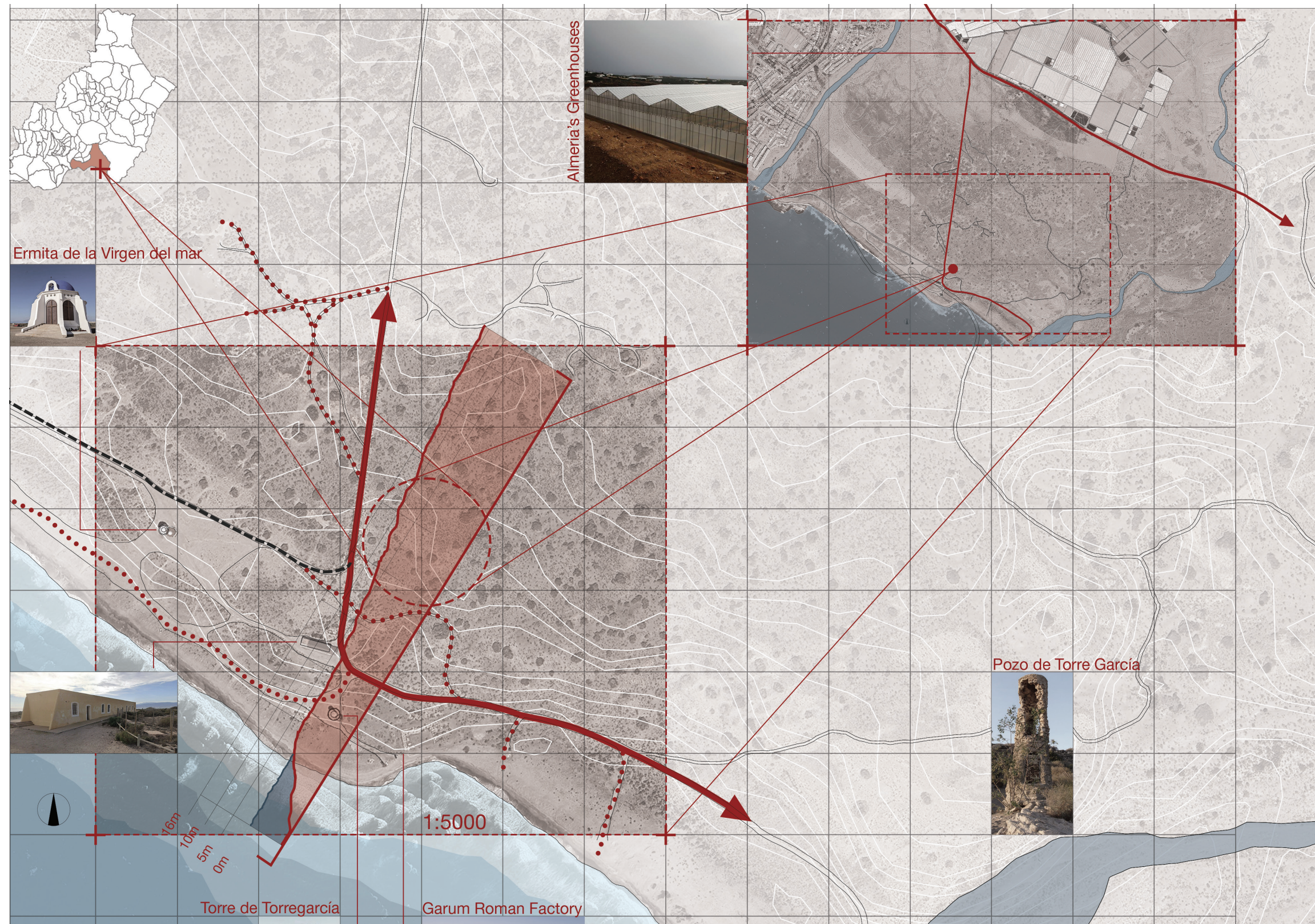


Thermal mass

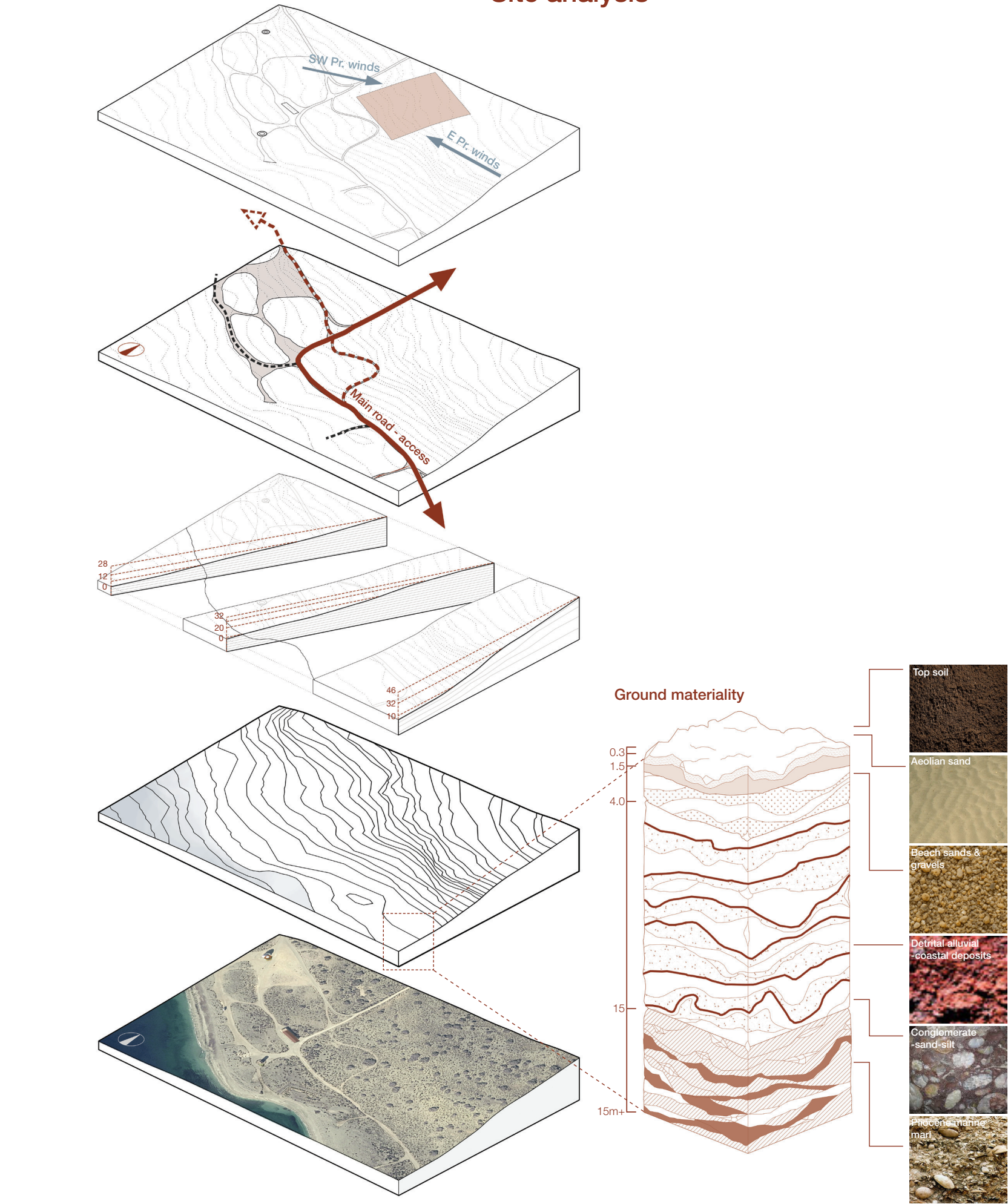




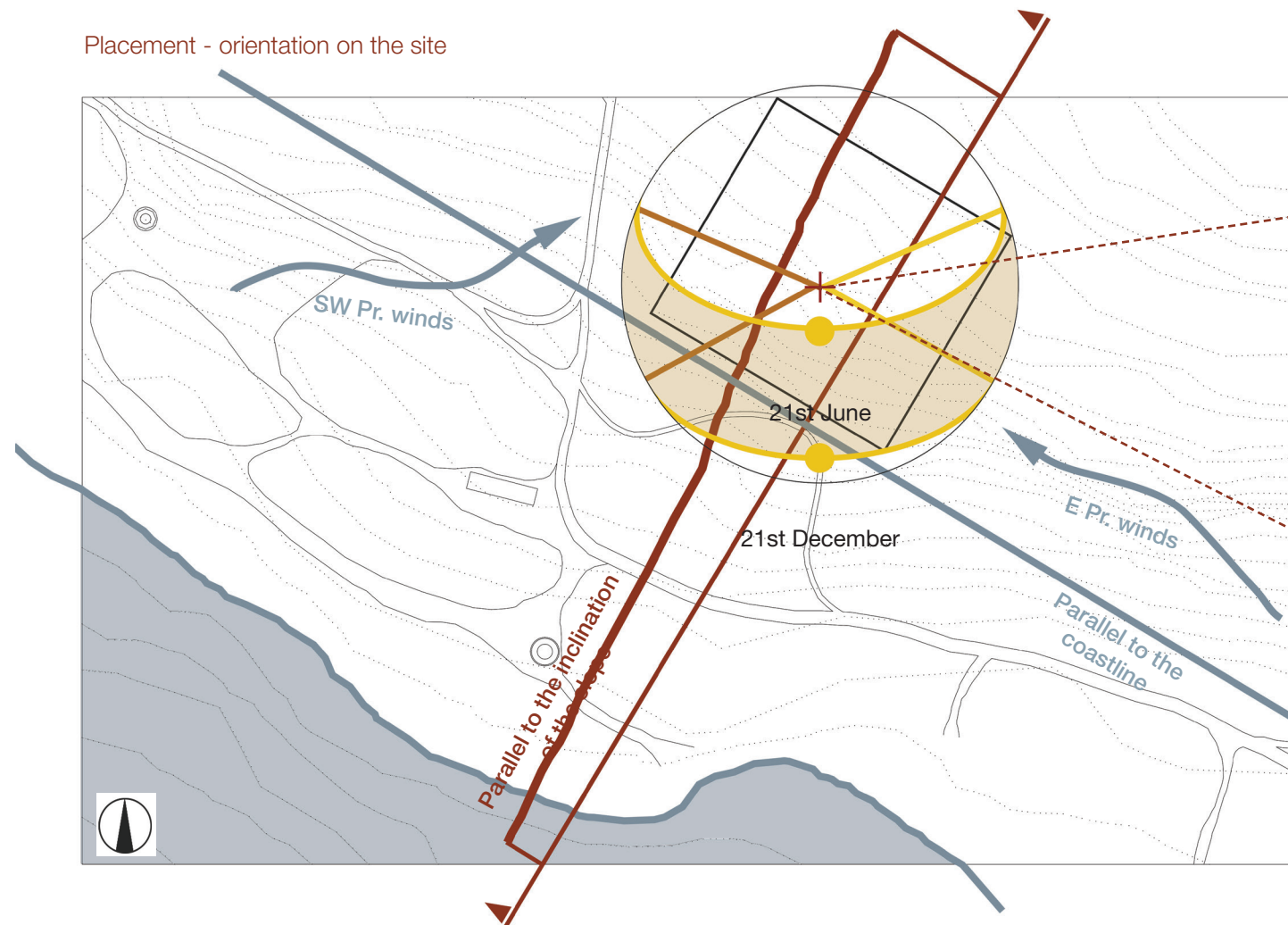
**For whom is it
designed and built?**



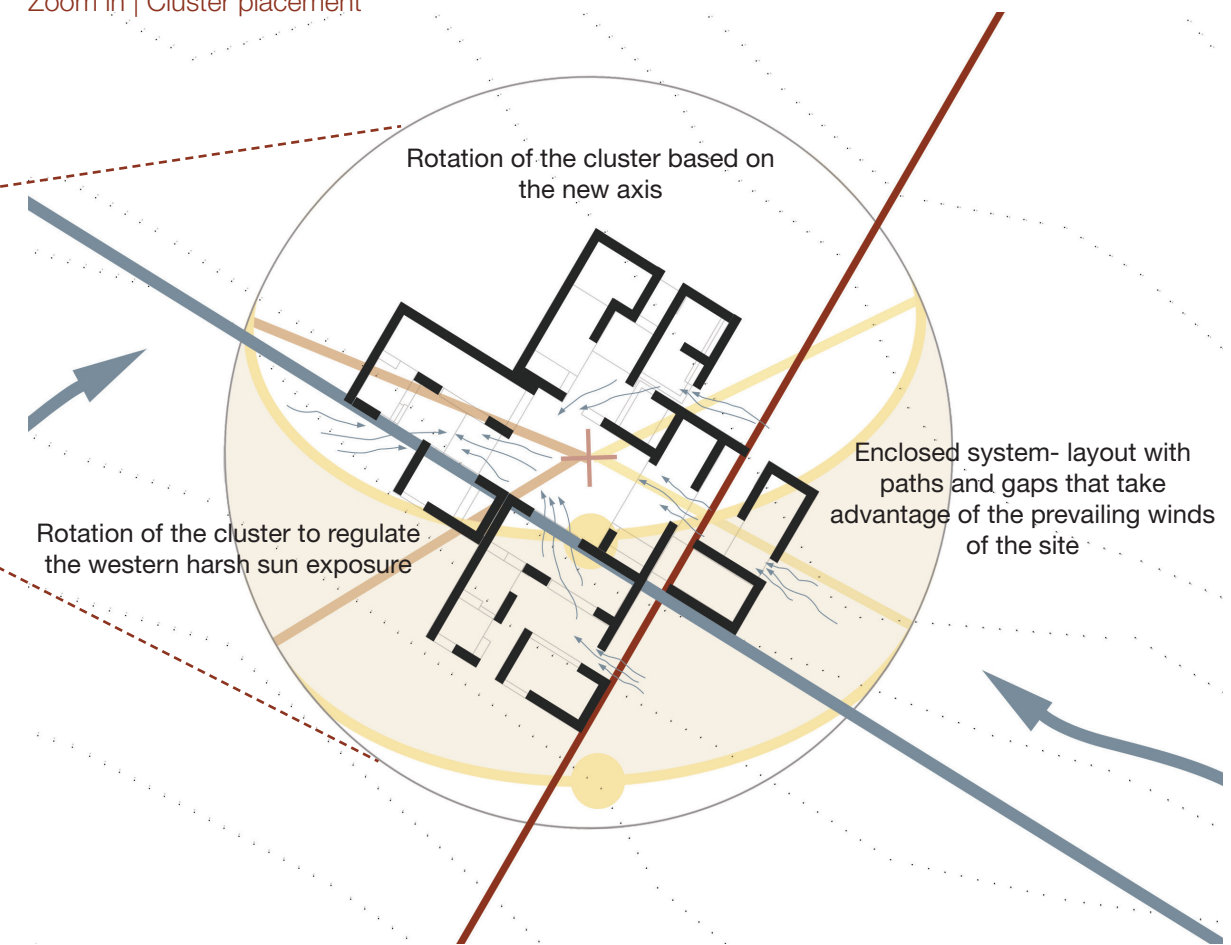
Site analysis



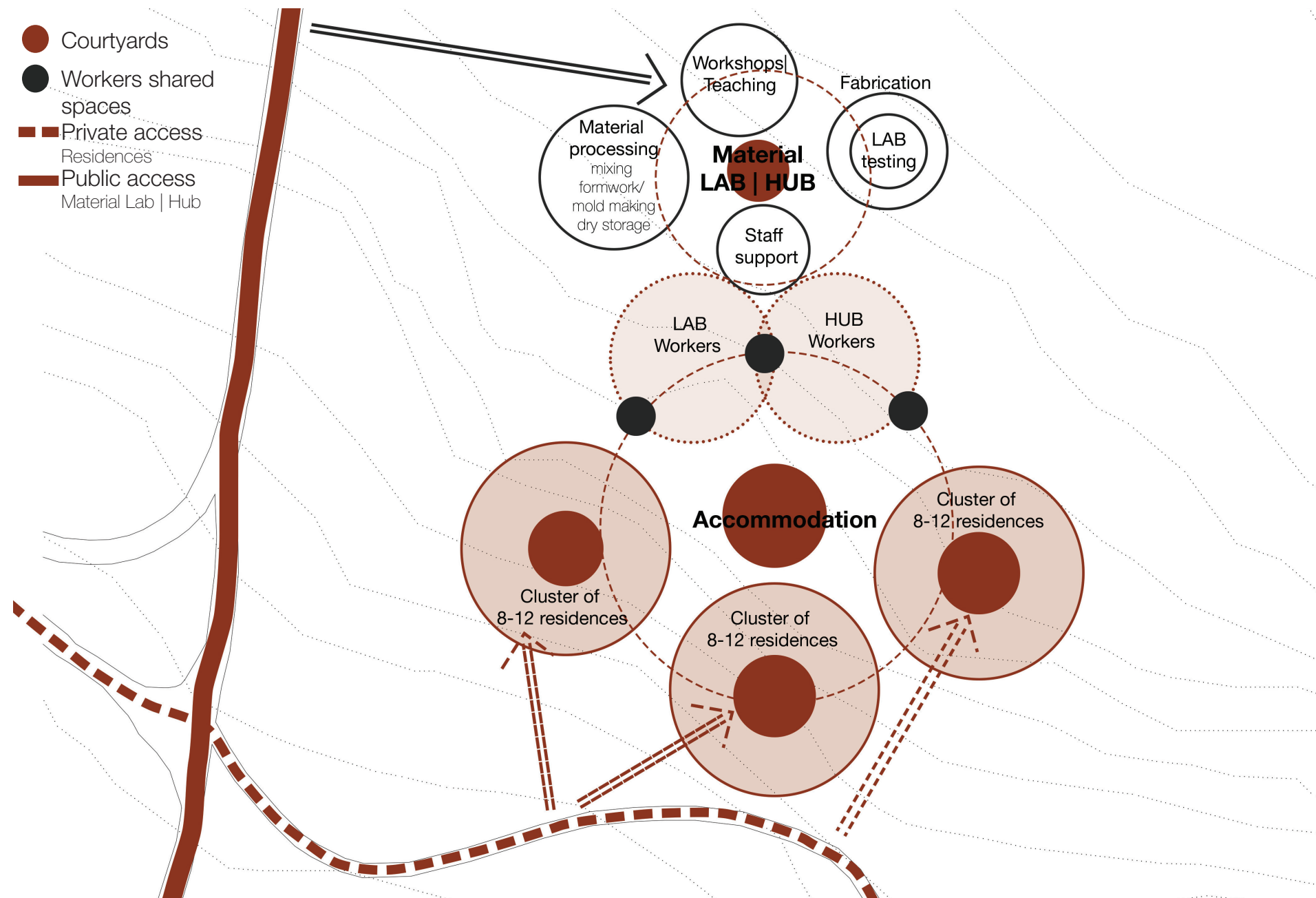
Placement - orientation on the site

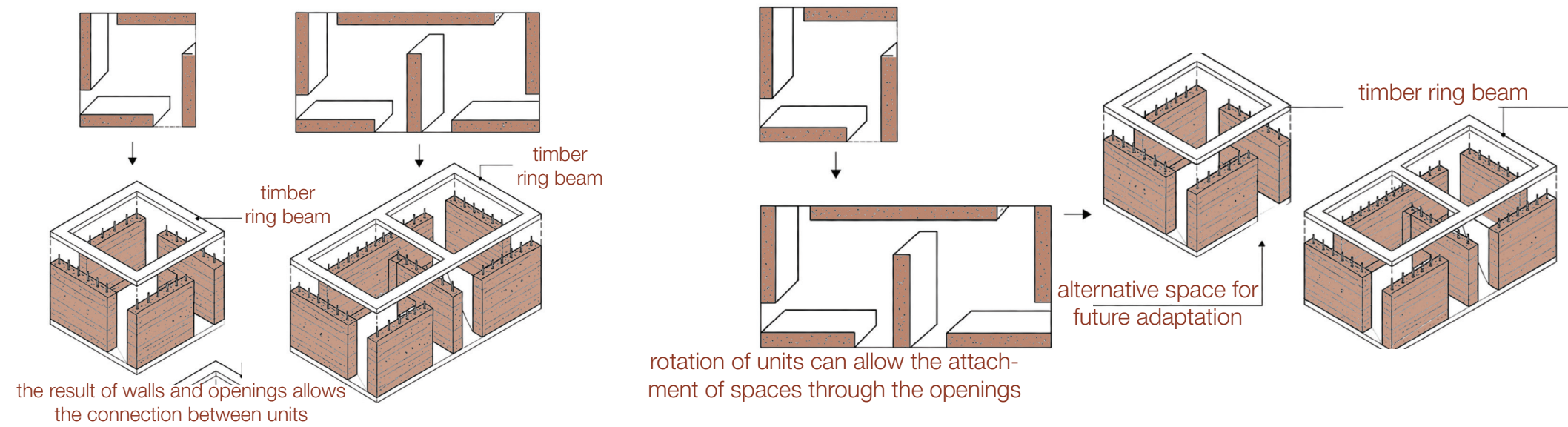


Zoom in | Cluster placement

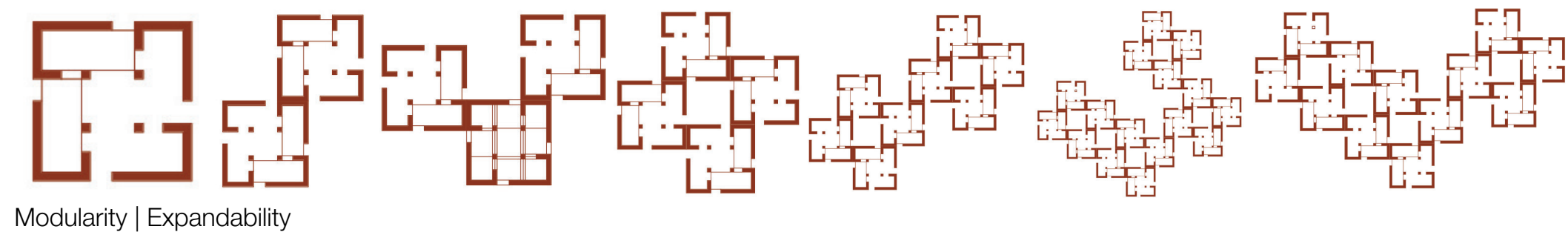


Program | Uses distribution

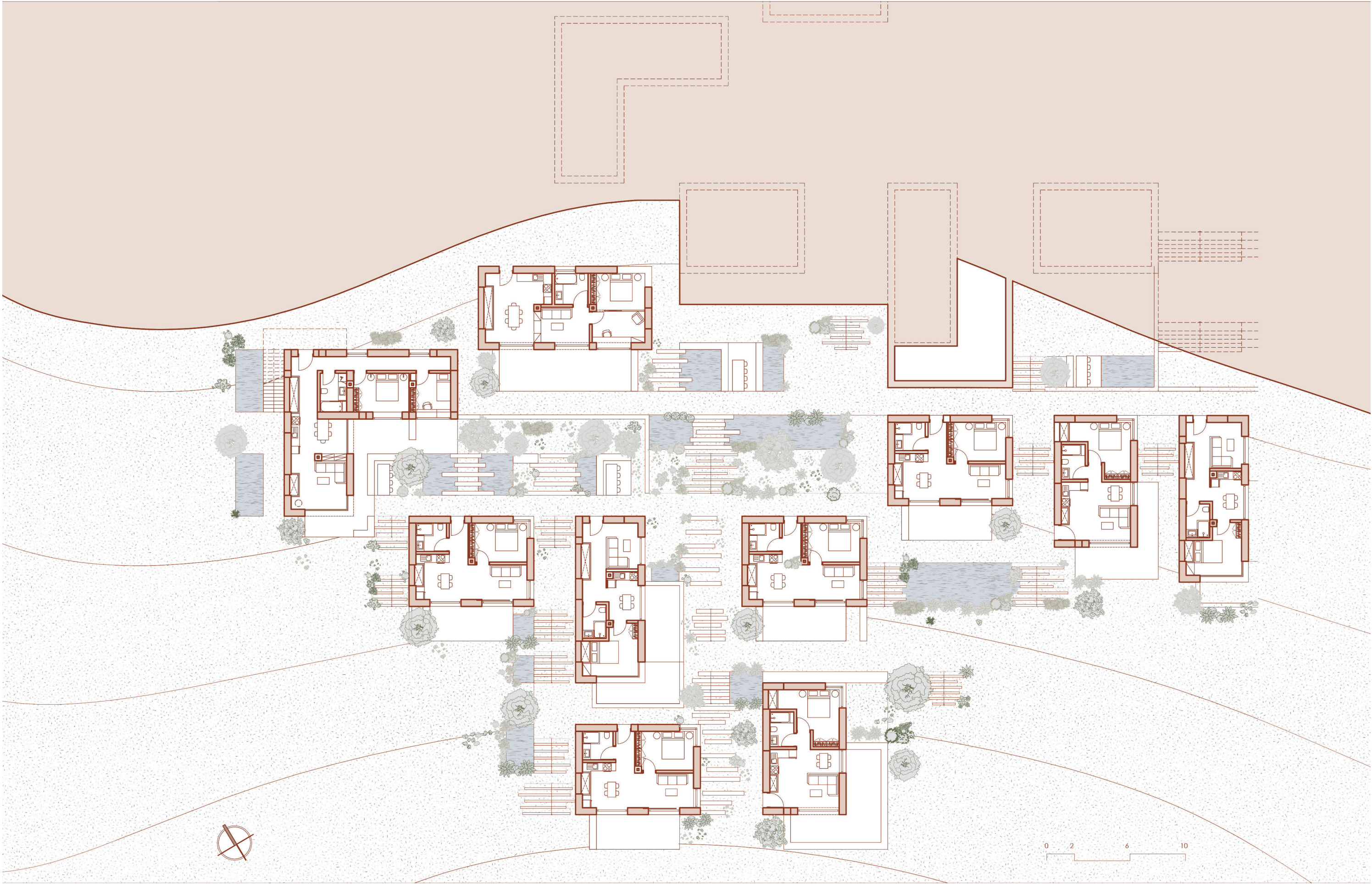


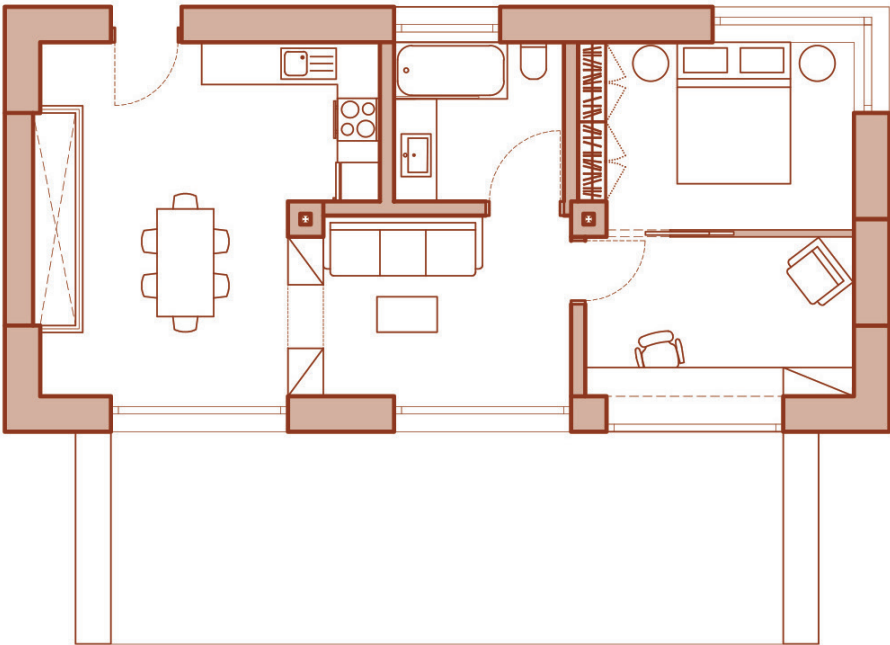


Prefabrication- design possibilities | Modularity

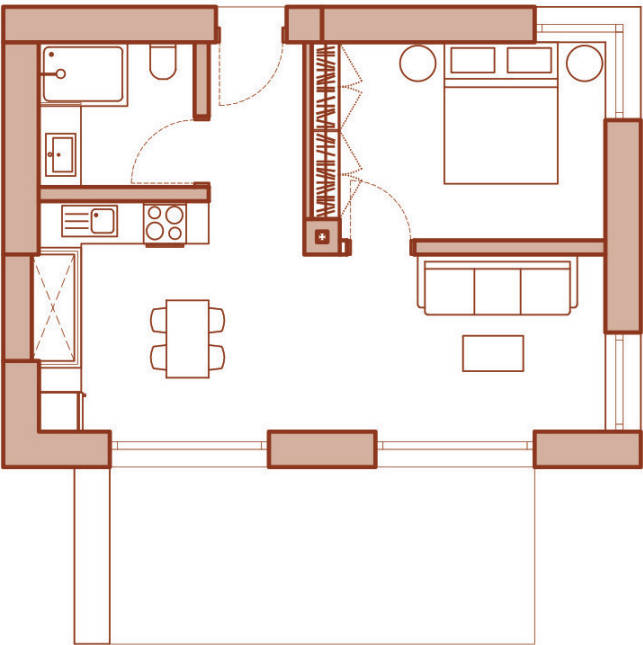


Modularity | Expandability

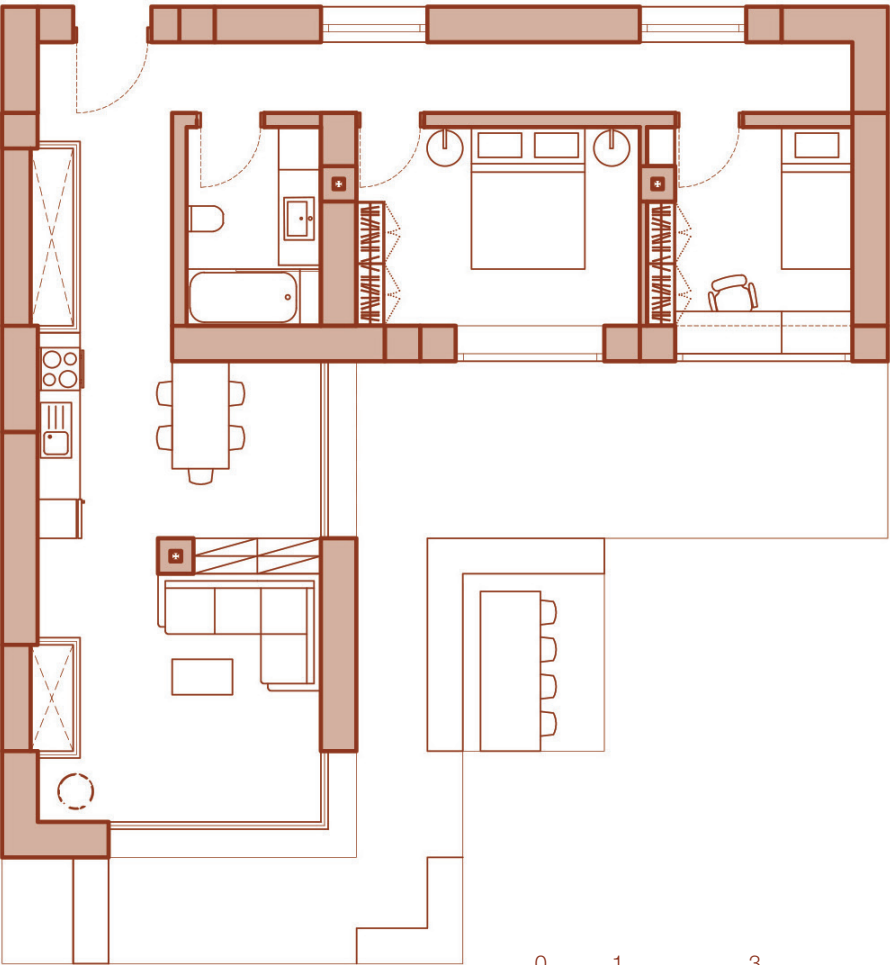




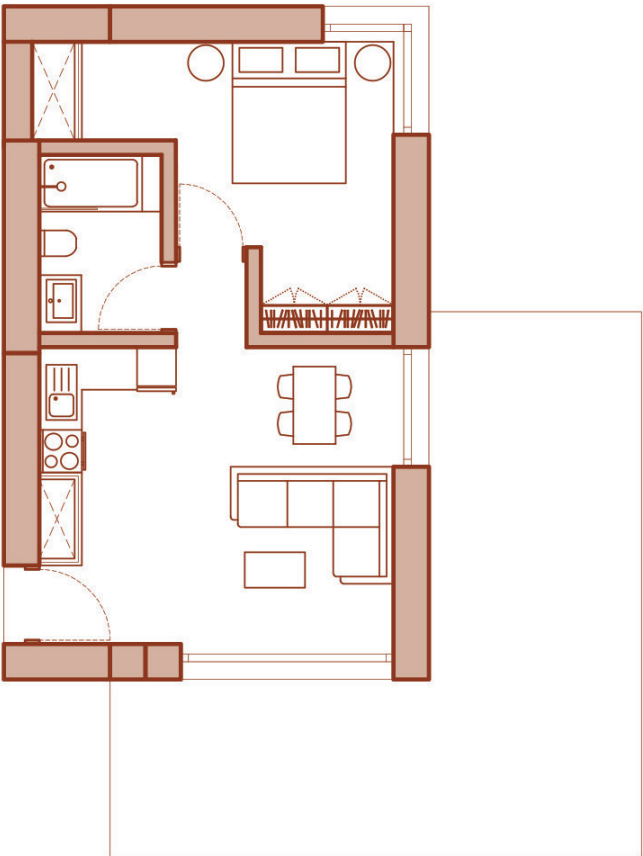
Type B_57 m2



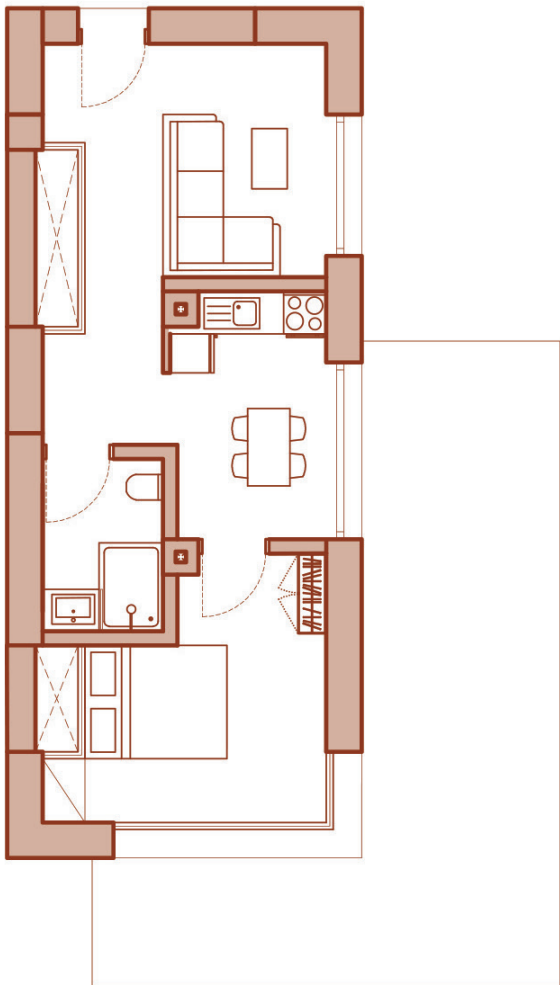
Type D_50 m2



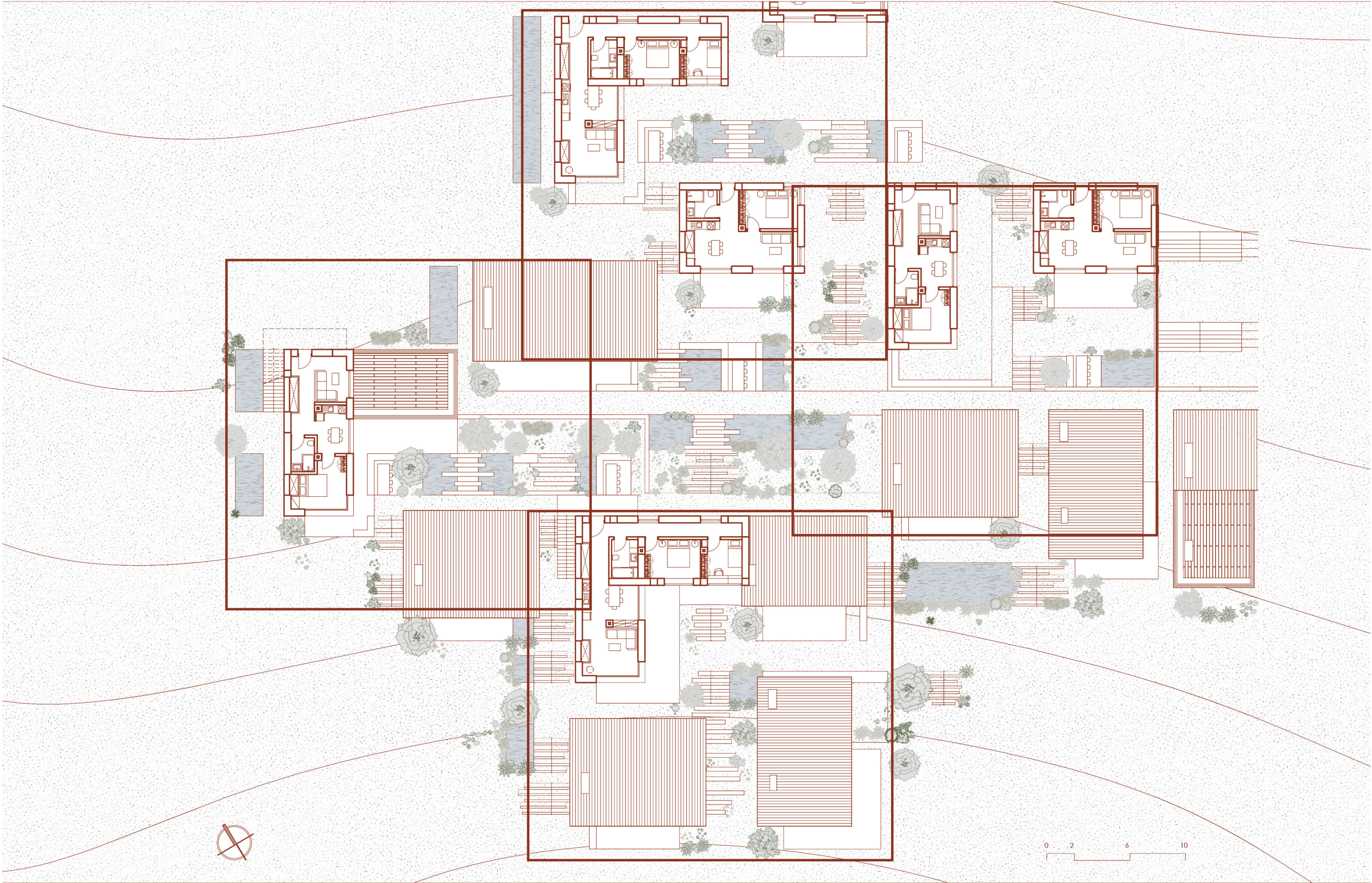
Type A_75 m2

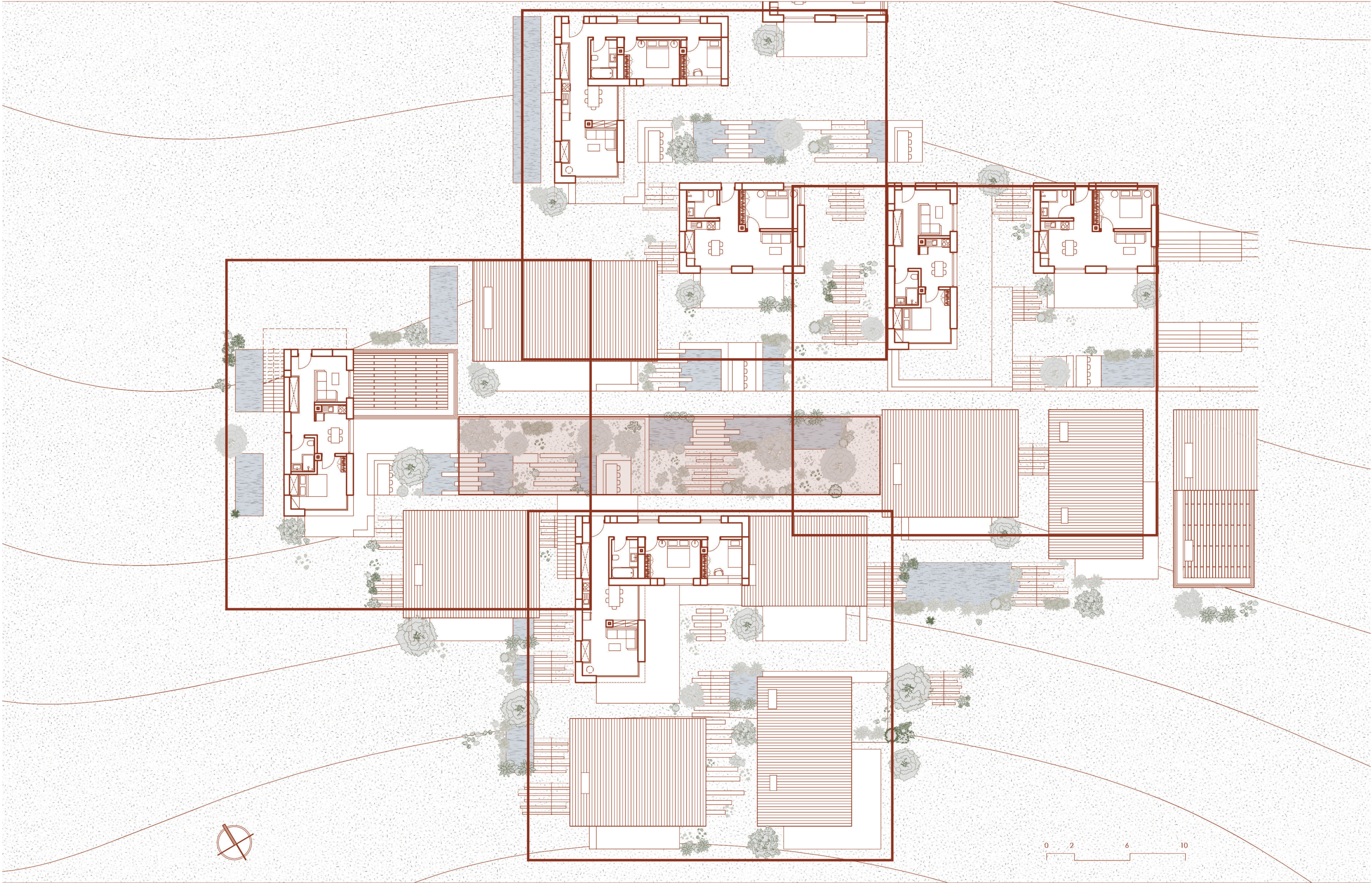


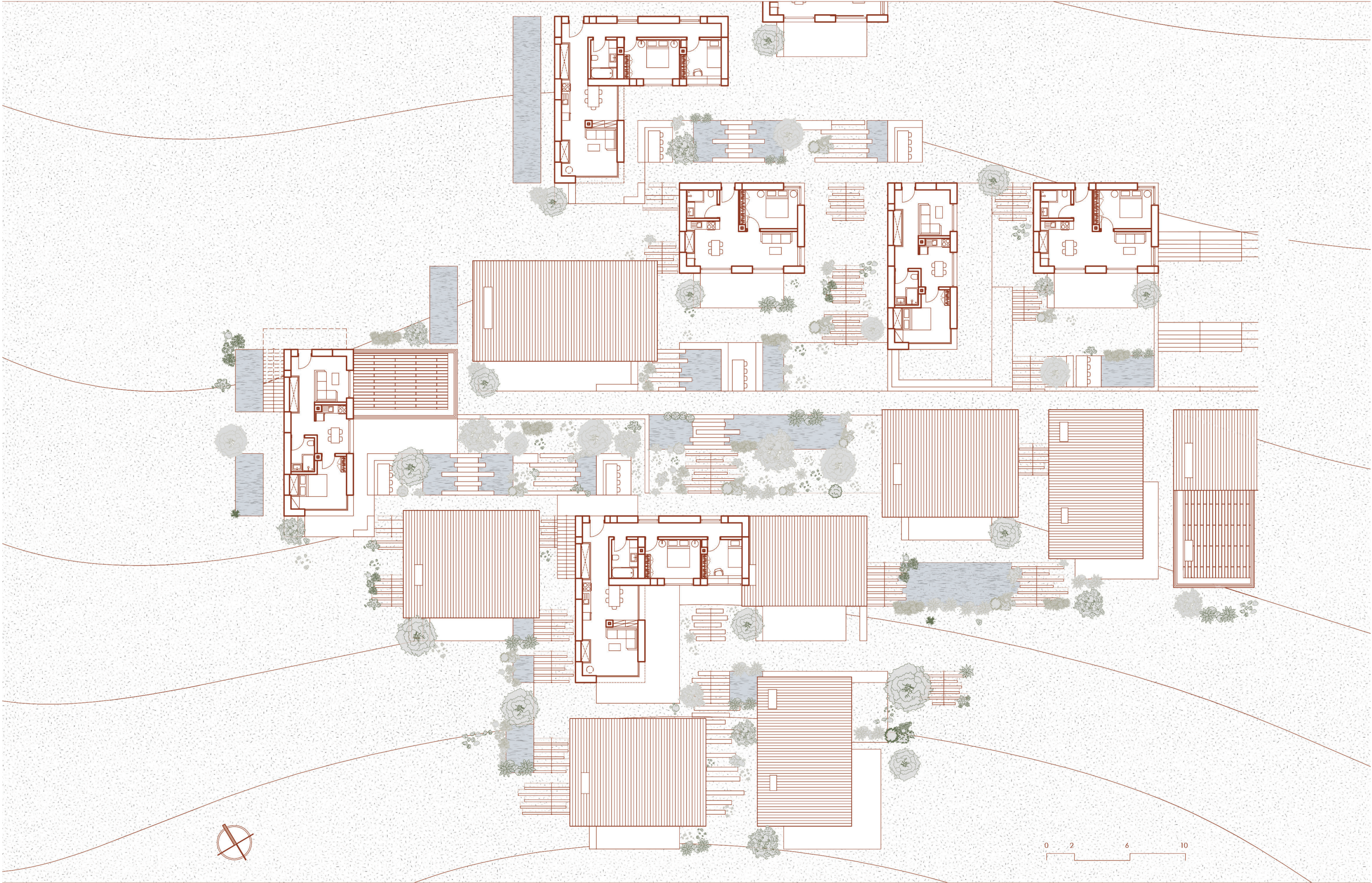
Type C_45 m2



Type E_45 m2

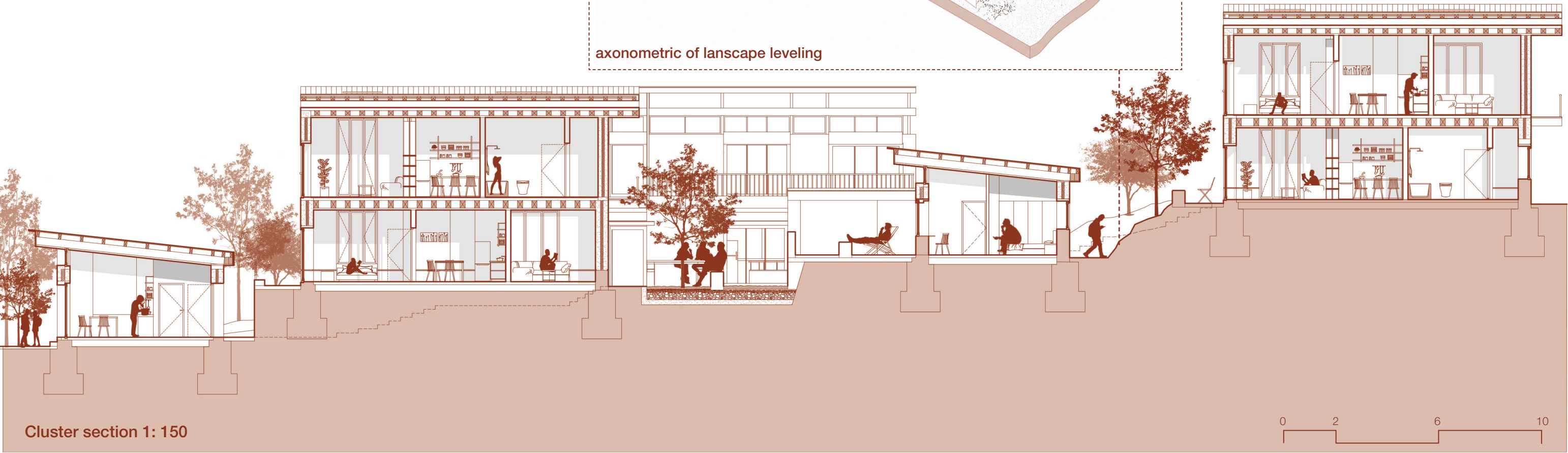
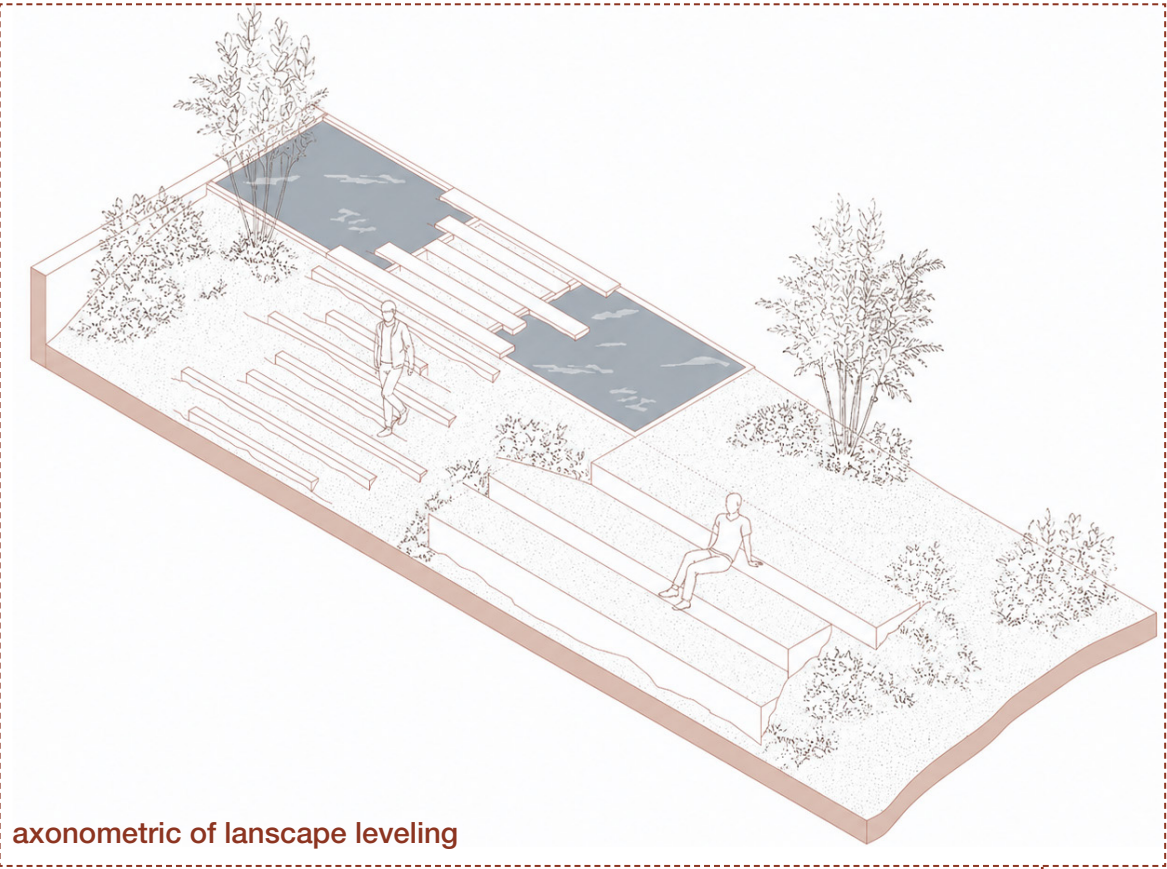




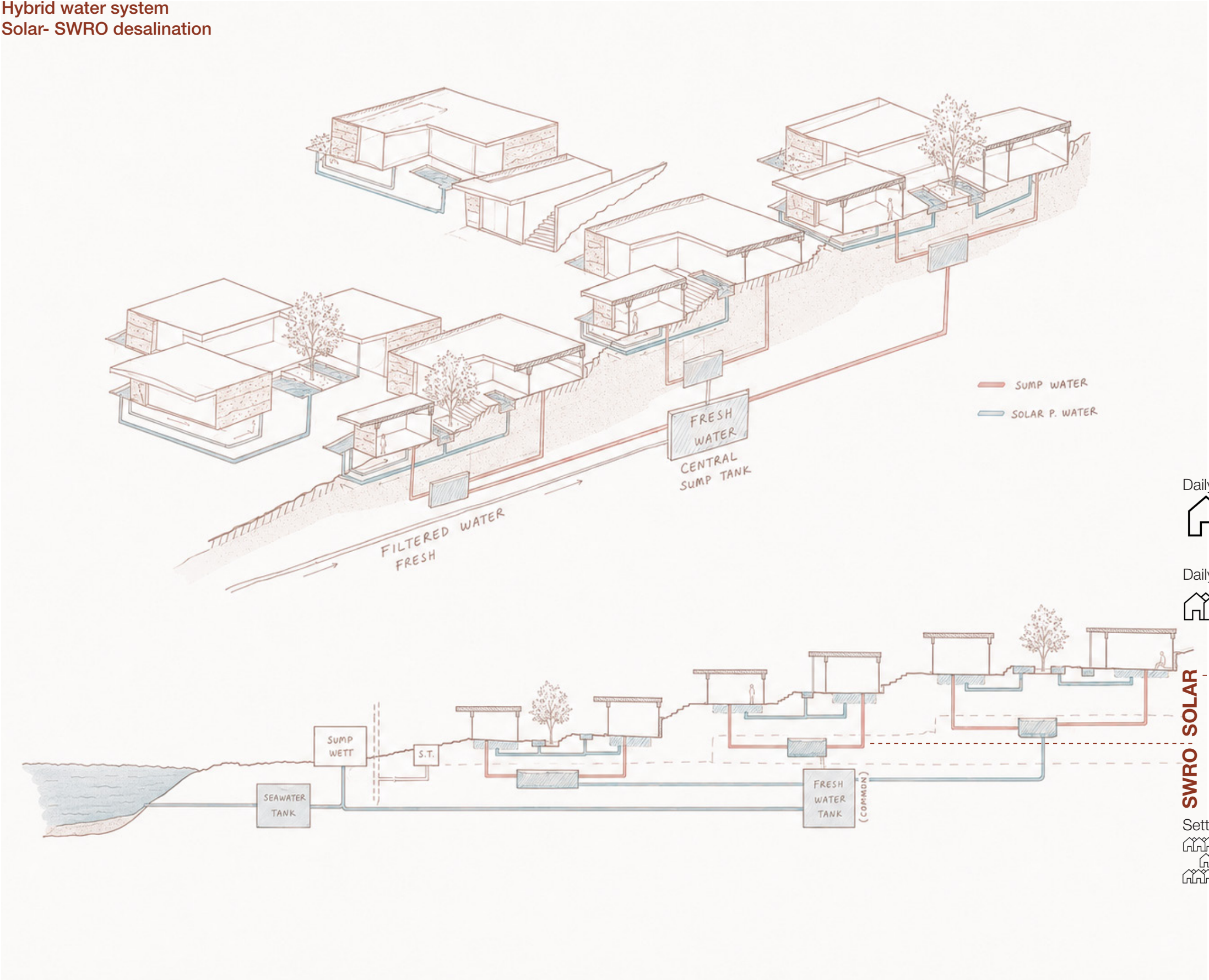








Hybrid water system
Solar- SWRO desalination



Daily needs per residence
200 L/d/r — 4 x 10 = 20 L/d critical need
4 x 40 = 160 L/d support from central network

Daily needs per cluster
1,600 L/d/c = 1.6m3 — 32 x 10 = 320 L/d
4 x 40 = 1,280 L/d

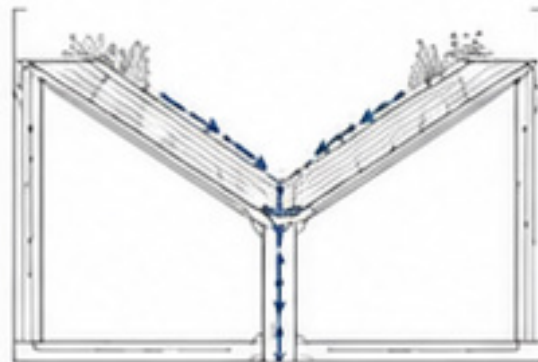
Passive solar stills daily capacity 4 L/m2/d — 320 / 4 = 80m2 active surface of solar stills
Safety: 100m2 of solar stills per cluster
Fresh water tank : 1-2 m3
Sea water tank: 2 m3

water tank product tank CIP
brine buffer network tank 24.5 - 30 m3 of tanks

Settlement level
8x 1.6= 12.8m3 /d — SOLAR 120 x 10 = 1,200 L/d=1.2m3/d
SWRO 120 x 40 = 4,800 L/d=4.8 m3/d

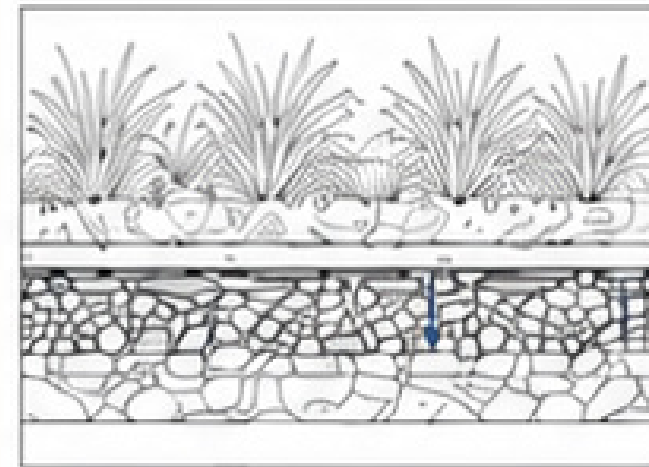
Integrated Rainwater Management System

1. Rainwater Collection from Butterfly Roof



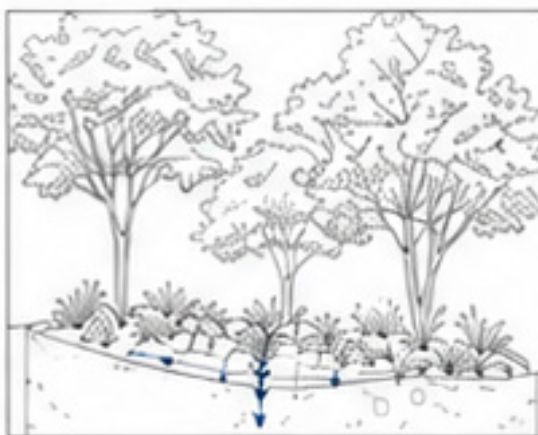
Rainwater is collected from the butterfly roof into a central gutter and directed through a downpipe to the first filtration stage.

3. Treatment & Filtration



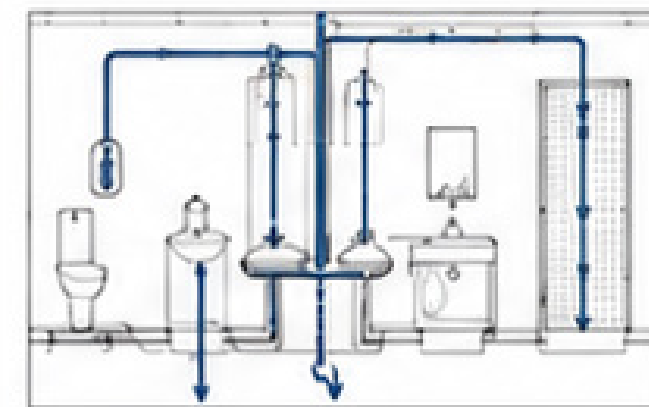
Collected water is directed to a series of natural and mechanical filtration stages: gravel & rock layers, bioretention with plants, and optional UV or sand filtration. Clean water is stored in tanks for later use.

2. Rainwater Collection from Trees & Landscape



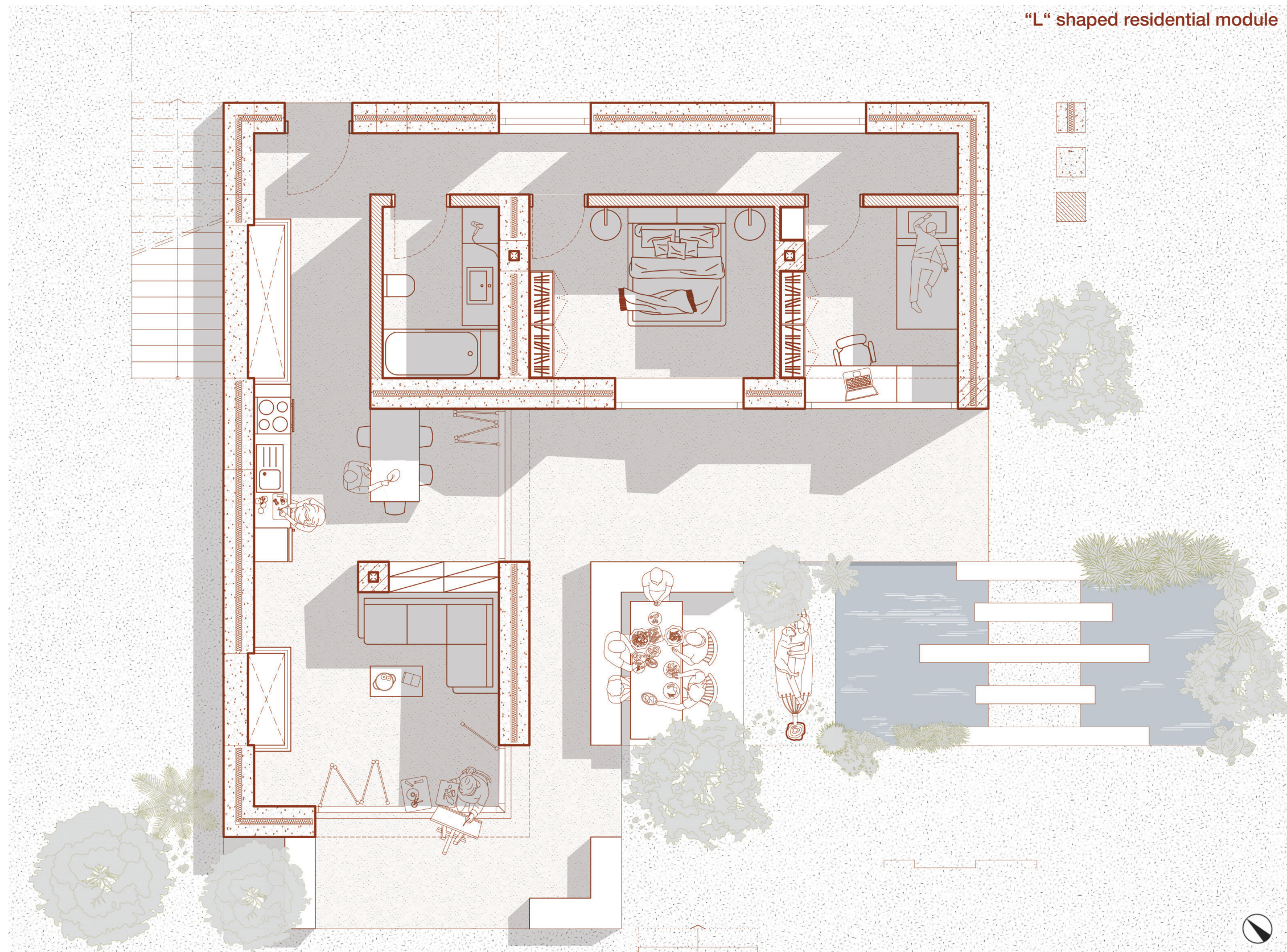
Rainfall is intercepted by tree canopies and falls to the ground. It is naturally filtered through soil, roots, and planting layers. The water is directed towards bioswales and infiltration zones.

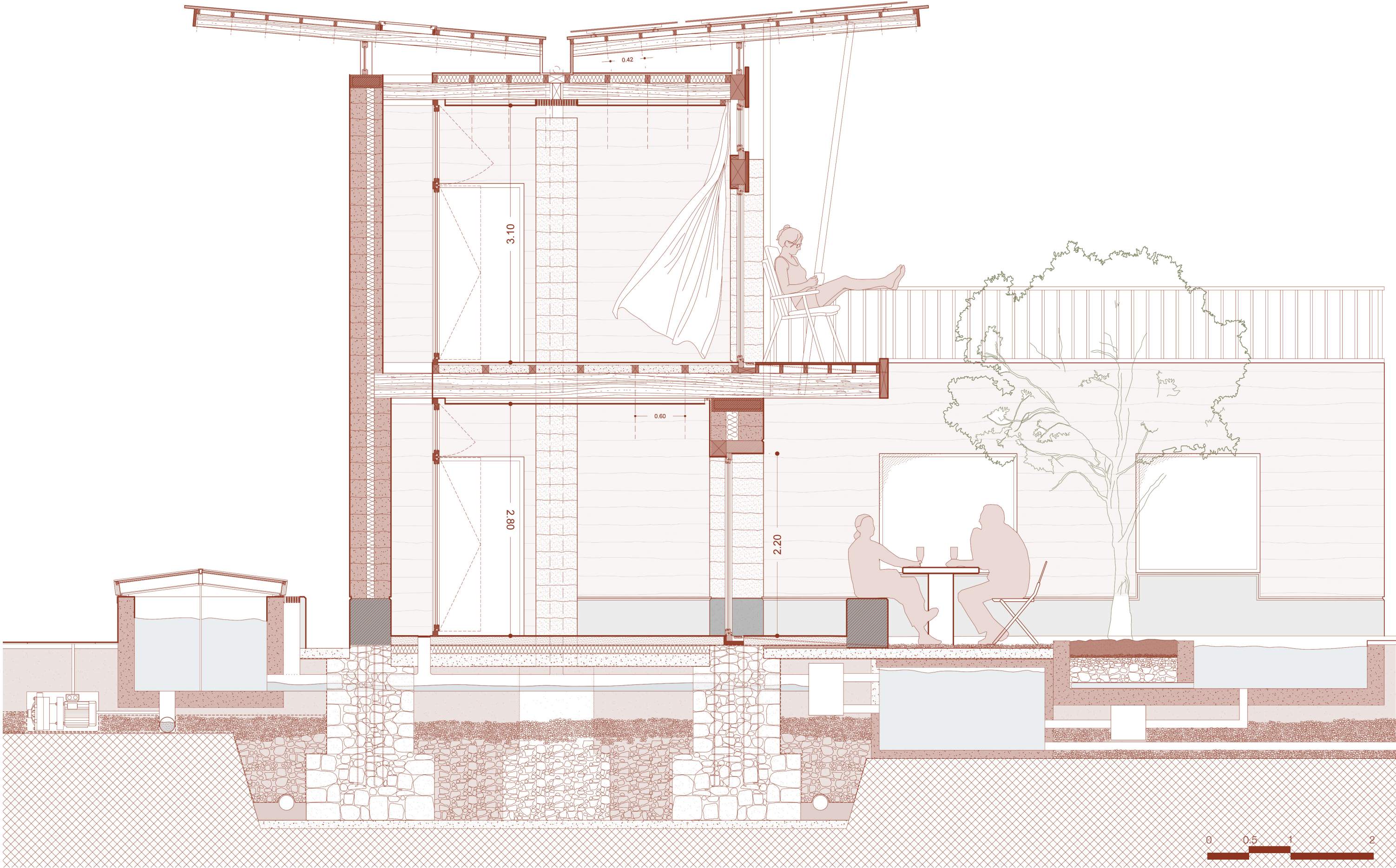
4. Water Reuse Back to the Building

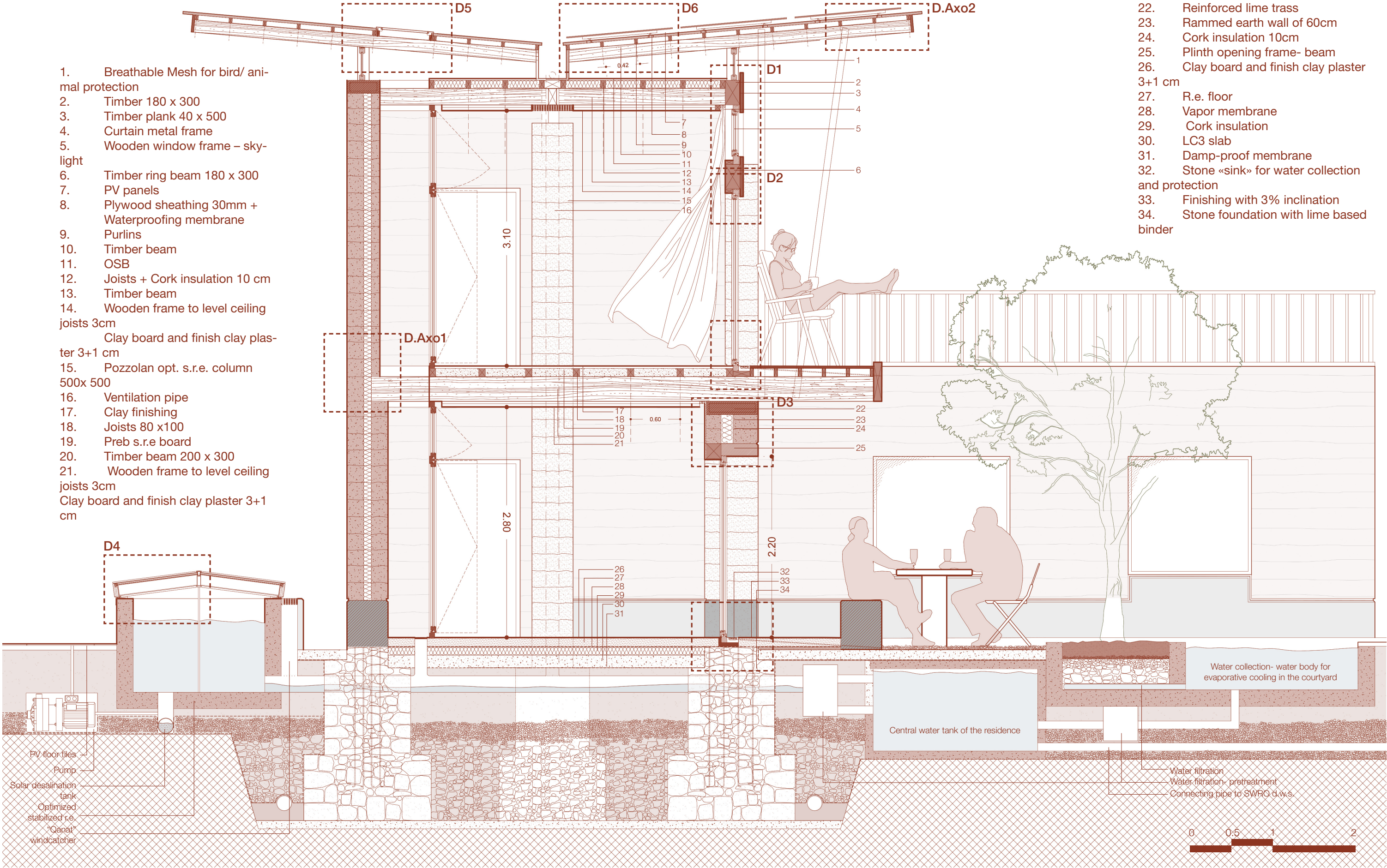


Filtered water is pumped back for non-potable uses such as: toilet flushing, irrigation, cleaning, cooling systems.

Excess water is used for landscape irrigation or recharged to the ground.



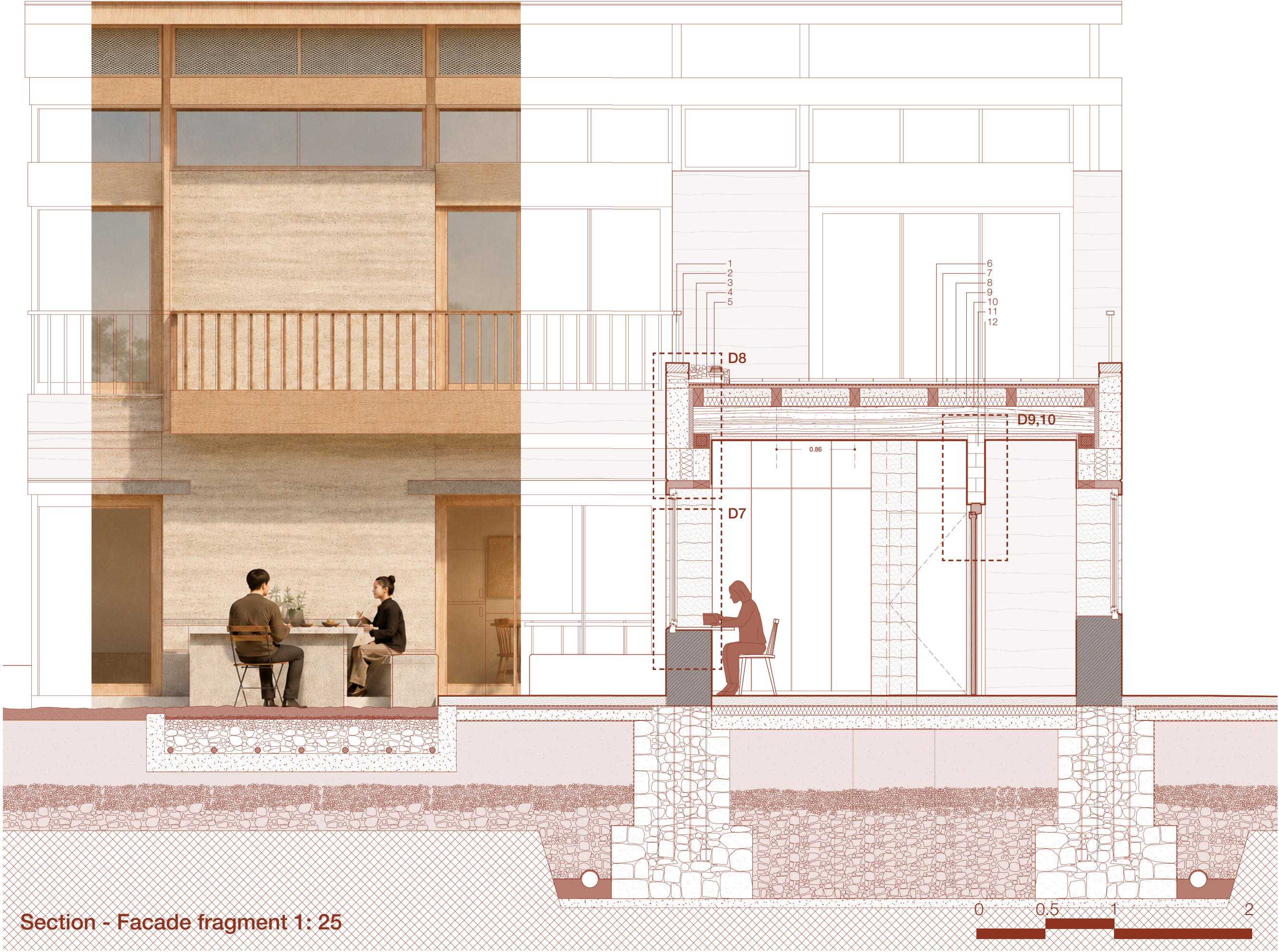




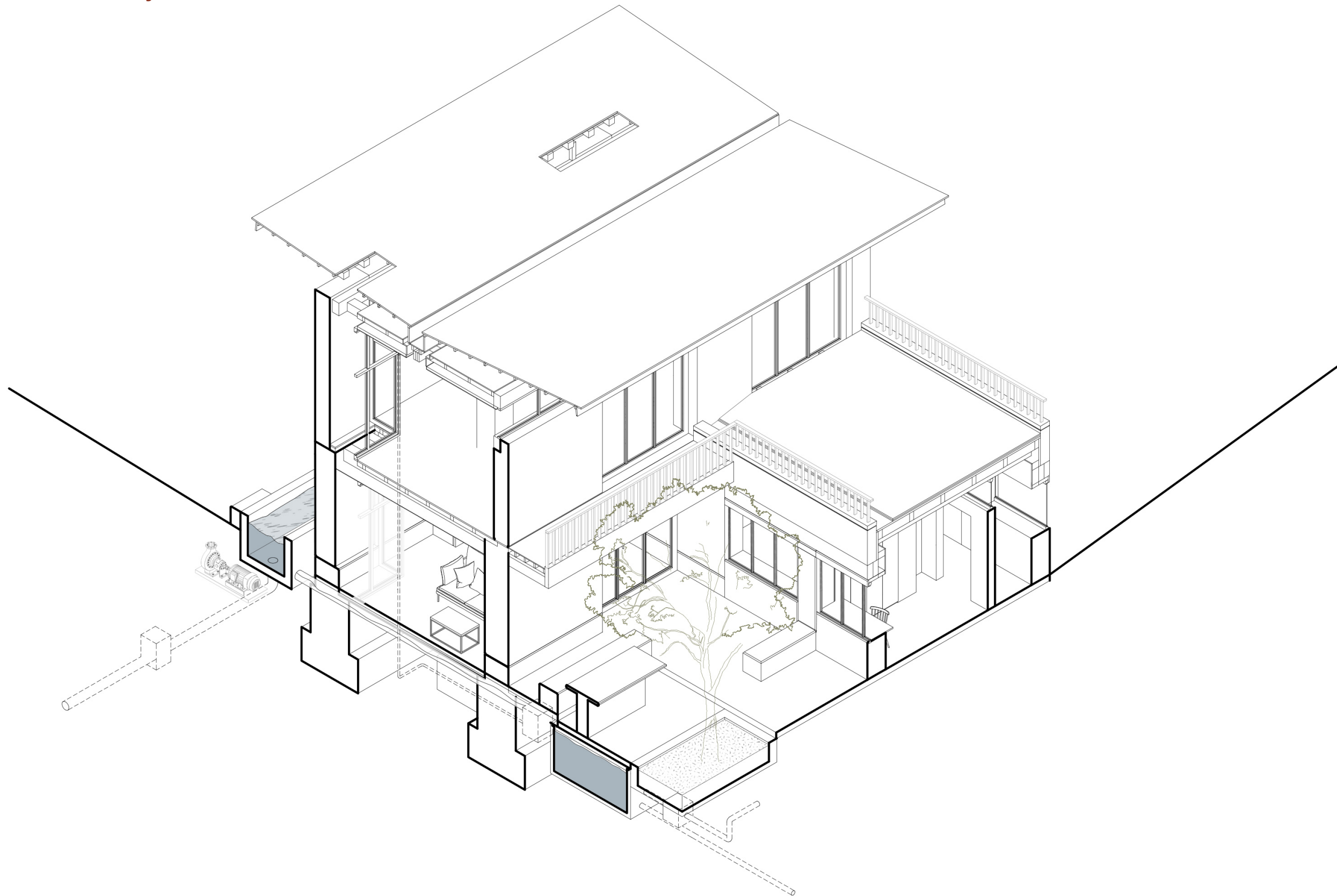


Section - Facade fragment

- 1. Wooden rail
- 2. Stone crown with 2% inclination +lime based binder+ In situ fabricated r.e.
- 3. Crushed volcanic gravel filling
- 4. Gutter for rain water collection
- 5. OSB board with water-proof membrane 2.5cm
- 6. Low fired mud tile covering 4cm
- 7. Damp-proof membrane
- 8. R.E. prefab panels
- 9. Cork insulation
- 10. Vapor membrane
- 11. CEB wall 20cm
- 12. Clay undercoat and finish plaster

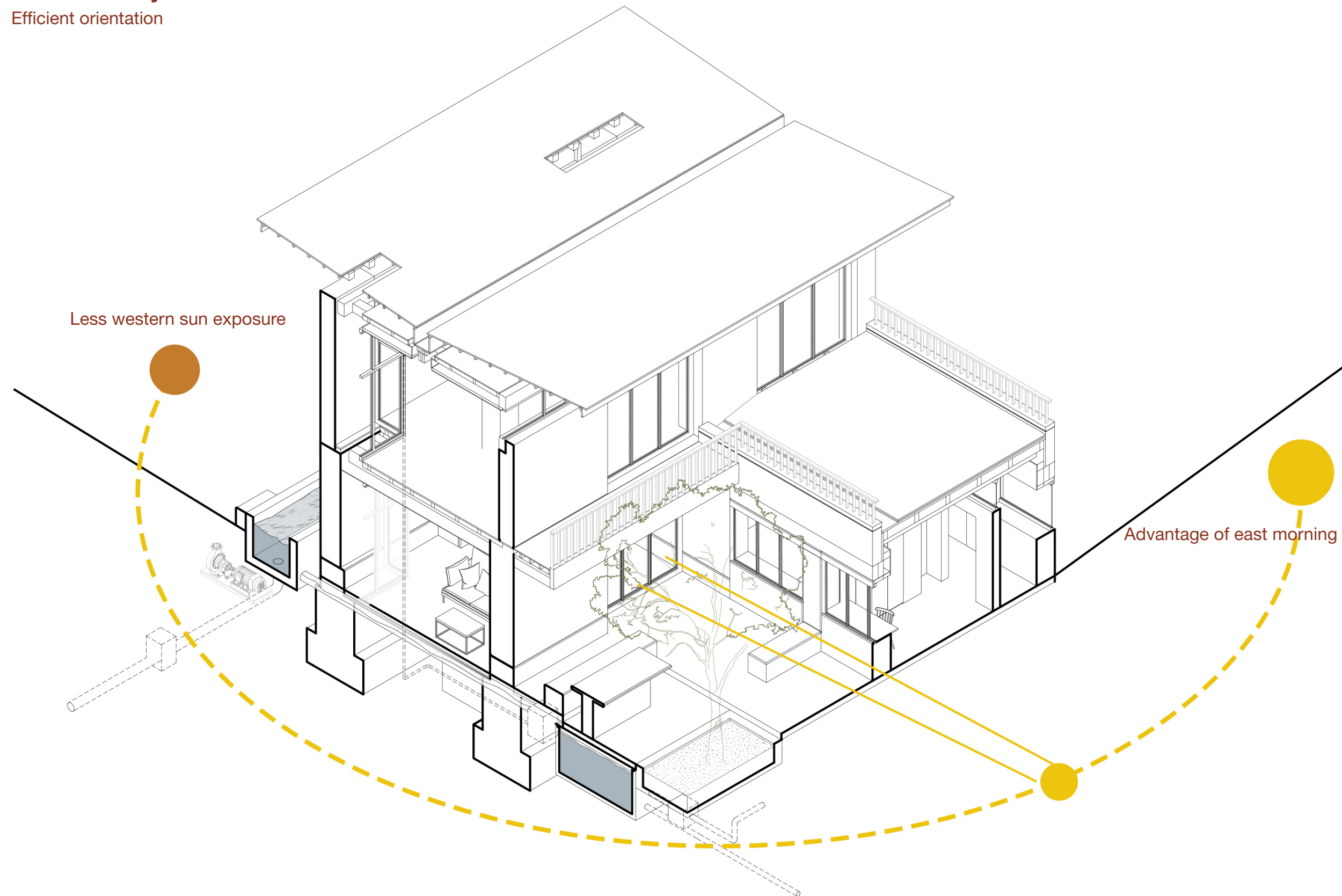


Climate analysis

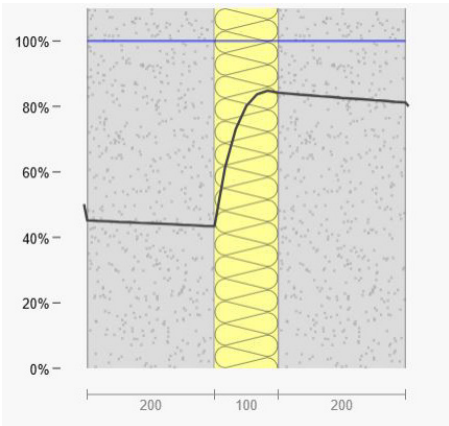
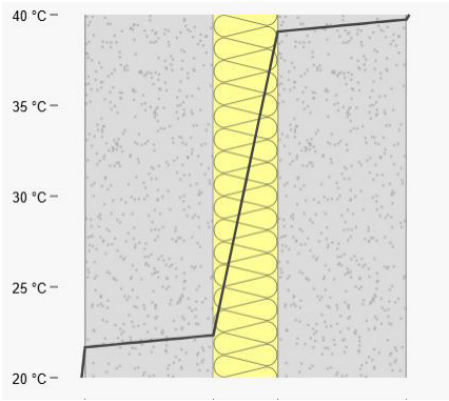
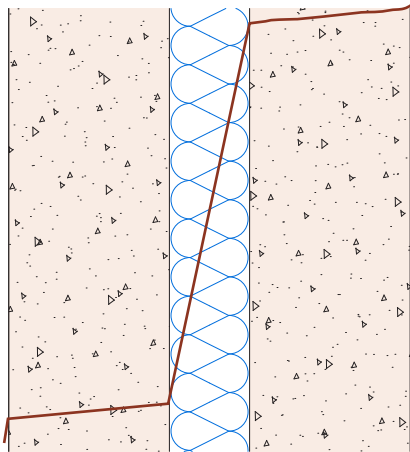
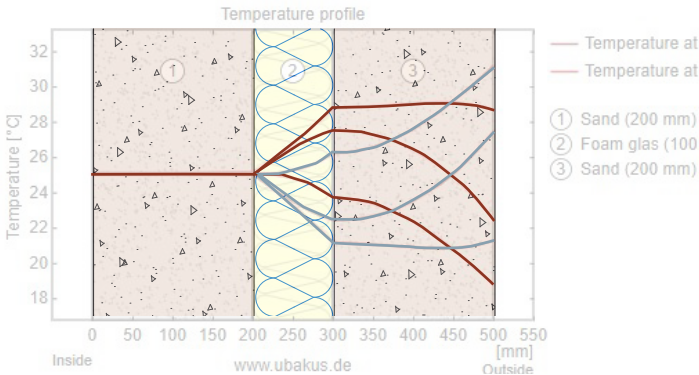
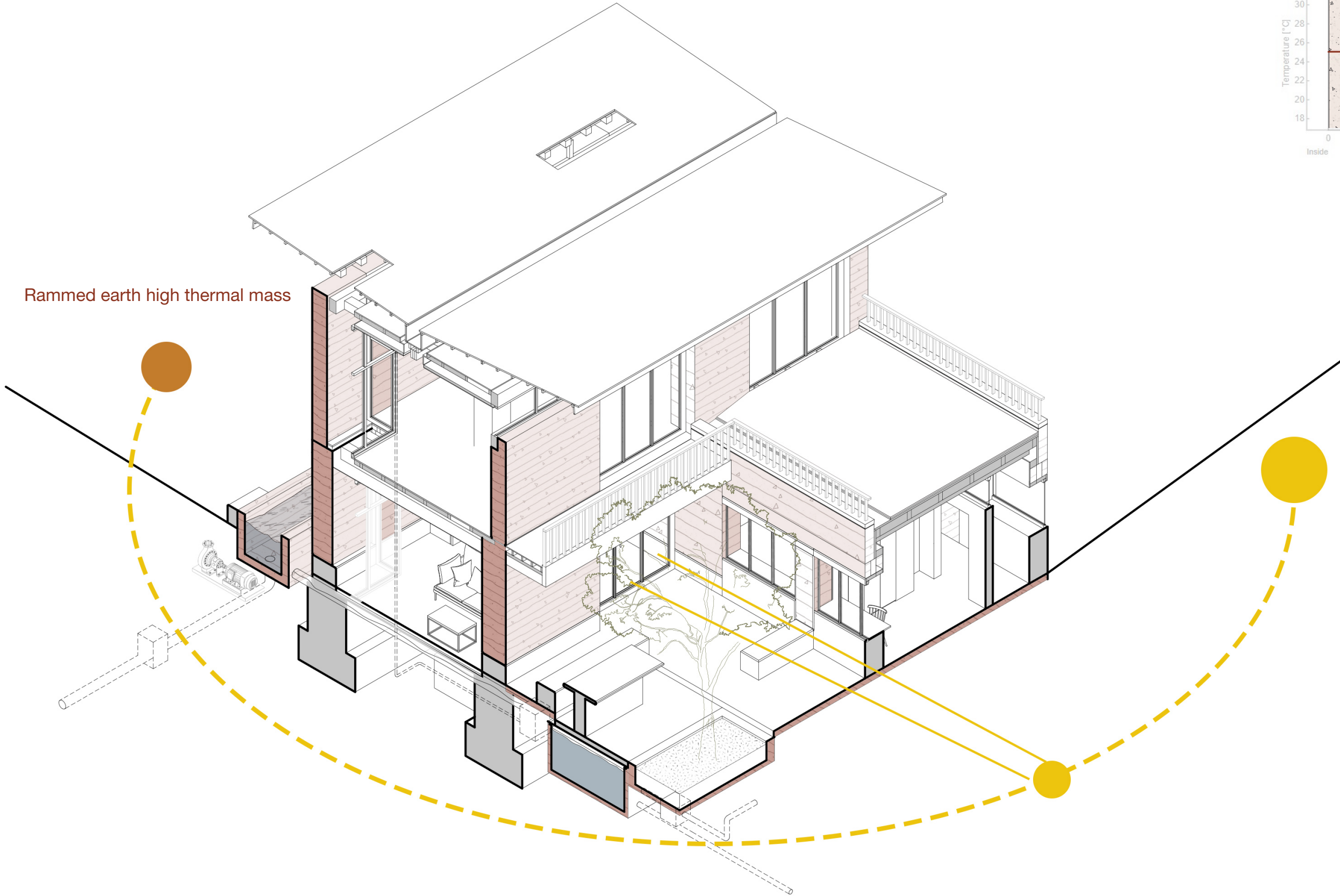


Climate analysis

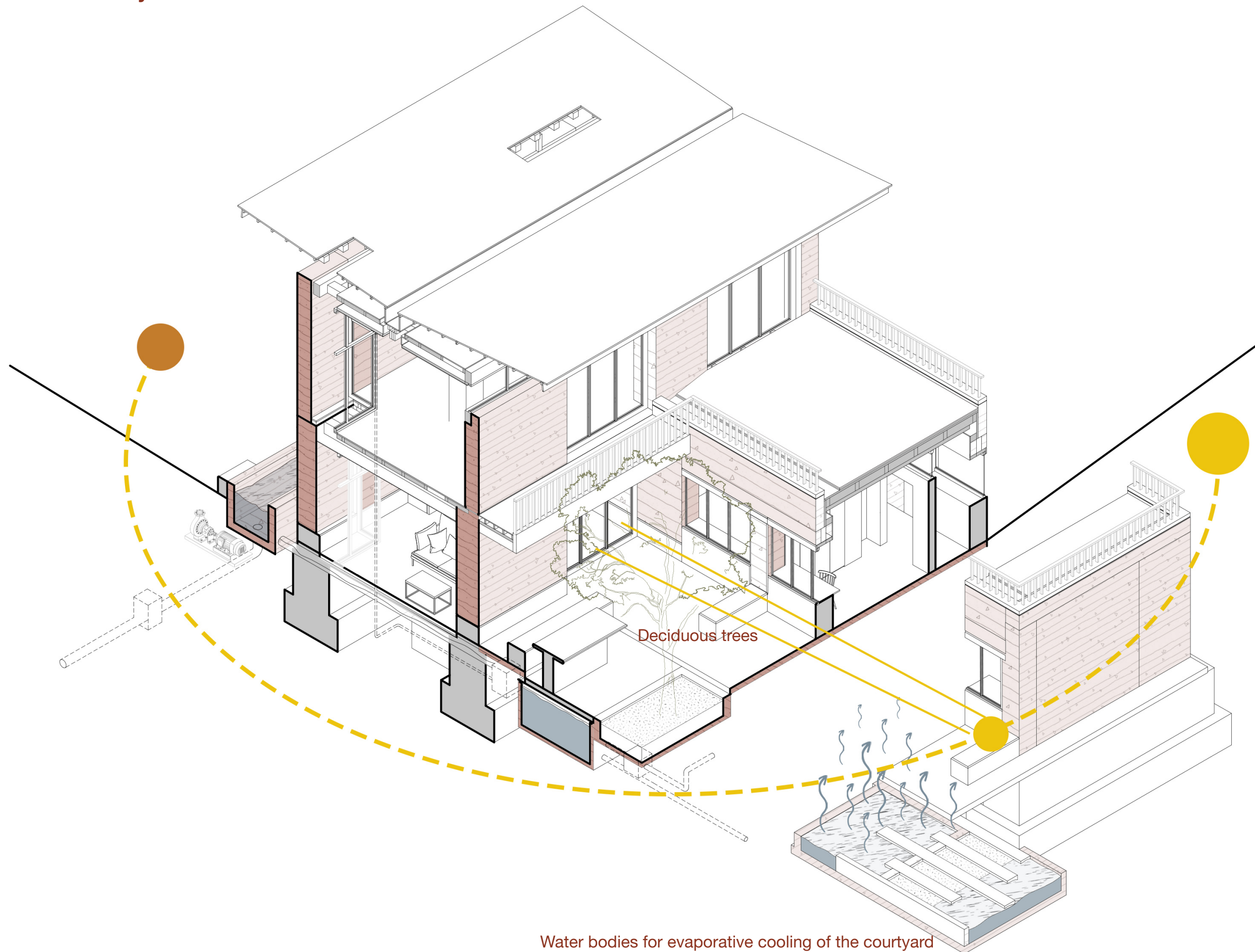
Efficient orientation



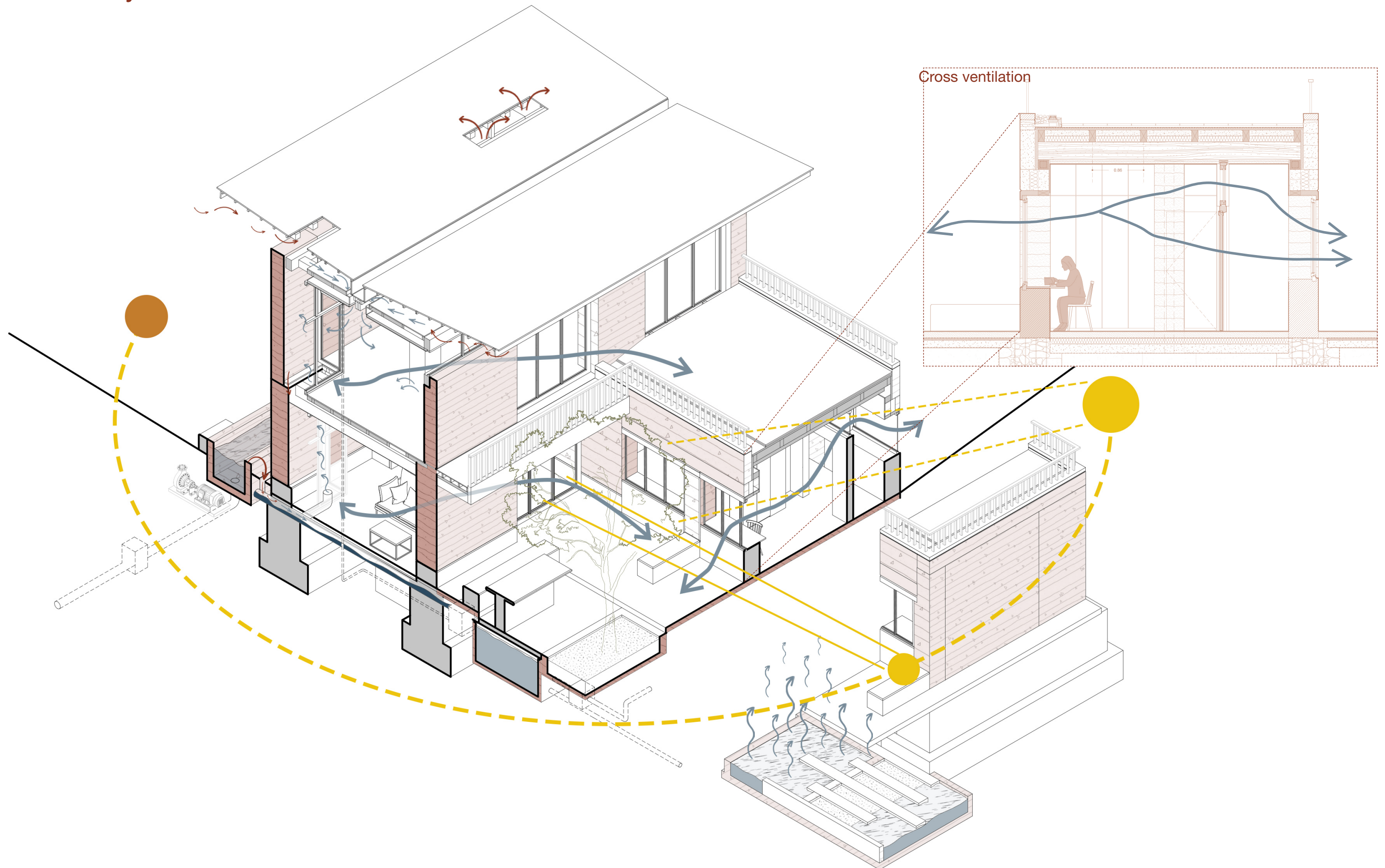
Climate analysis



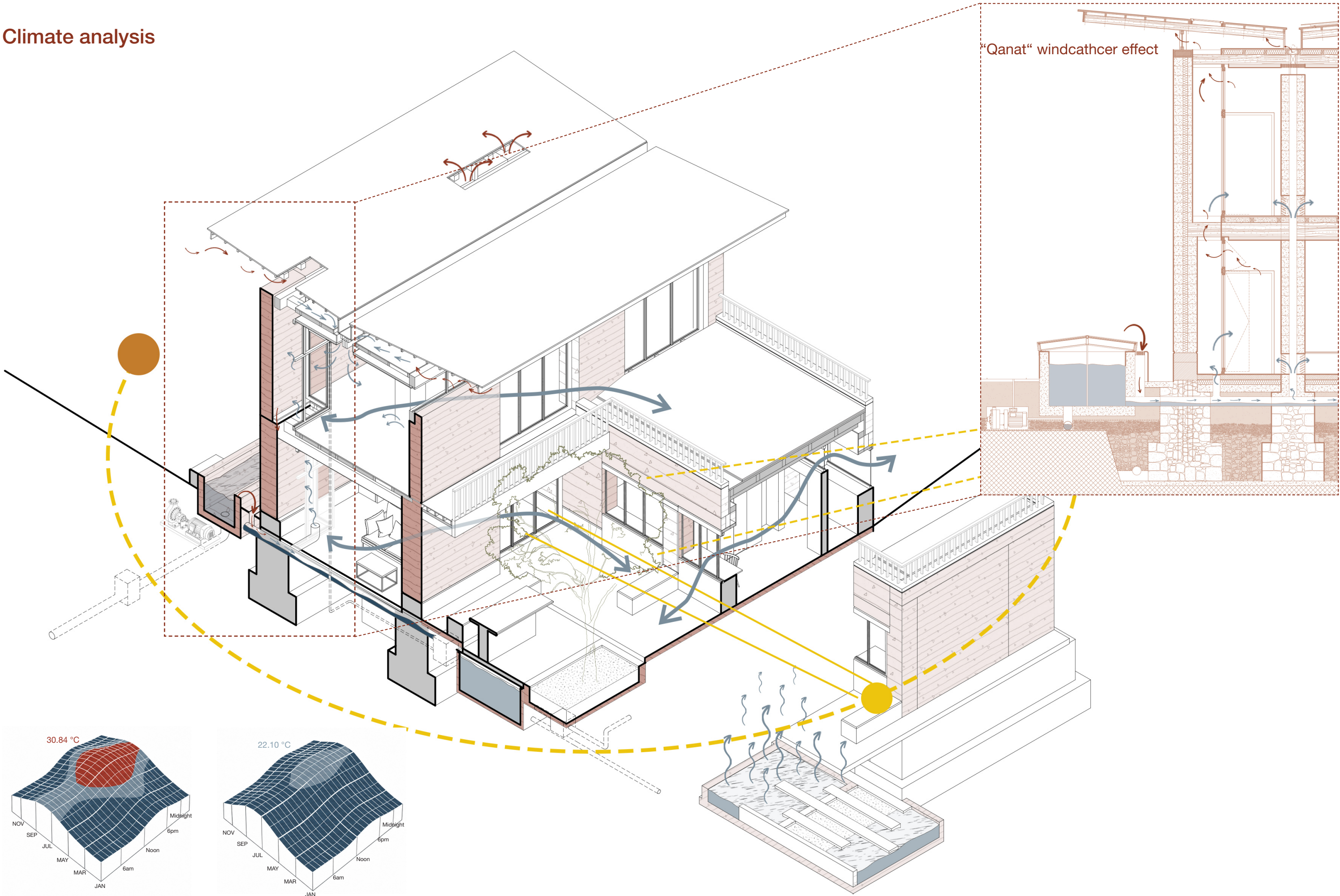
Climate analysis



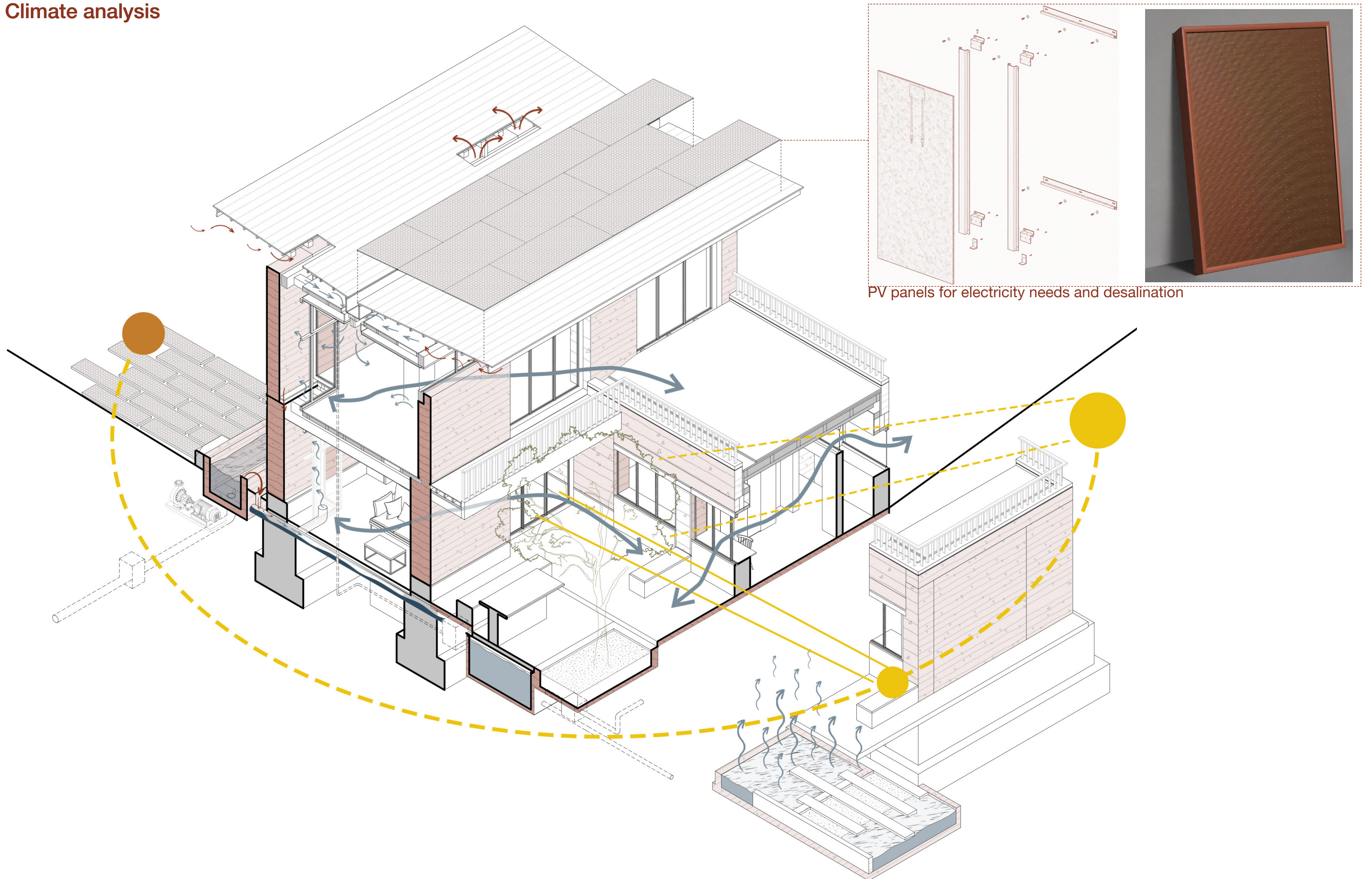
Climate analysis



Climate analysis

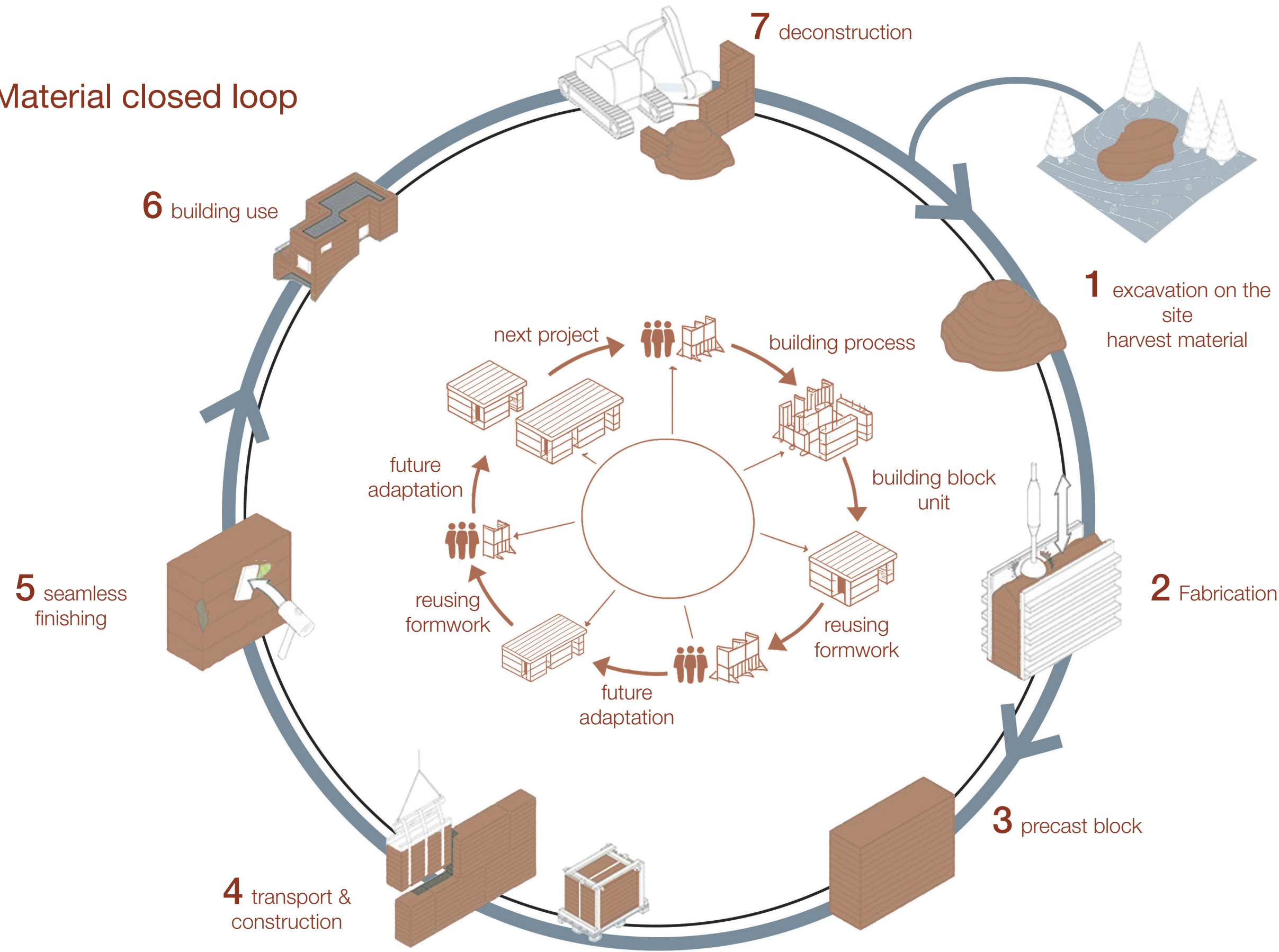


Climate analysis



Construction logic and order

Material closed loop



Excavation for water system per cluster

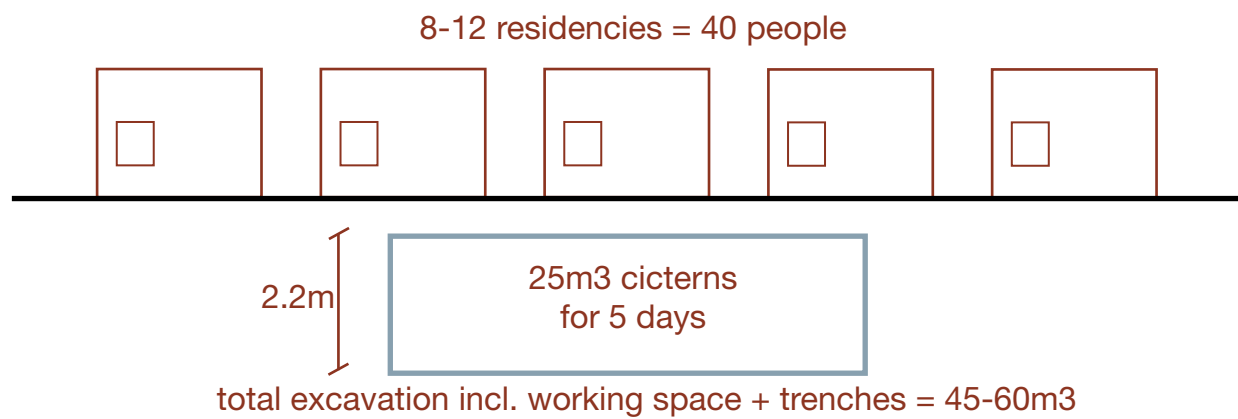


local material extraction

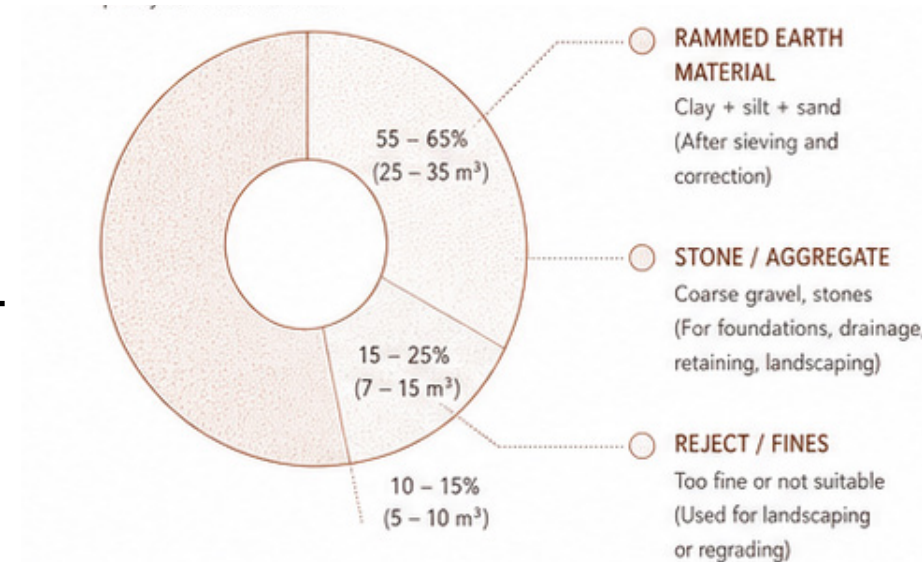


rammed earth construction

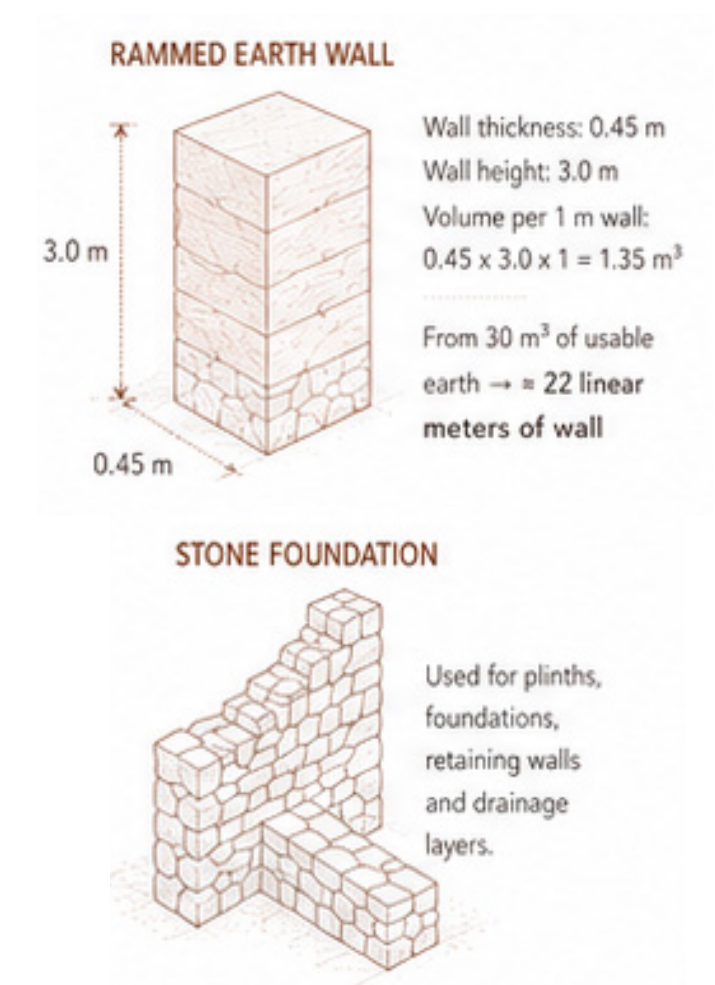
1. Underground water system per cluster



2. Excavated material

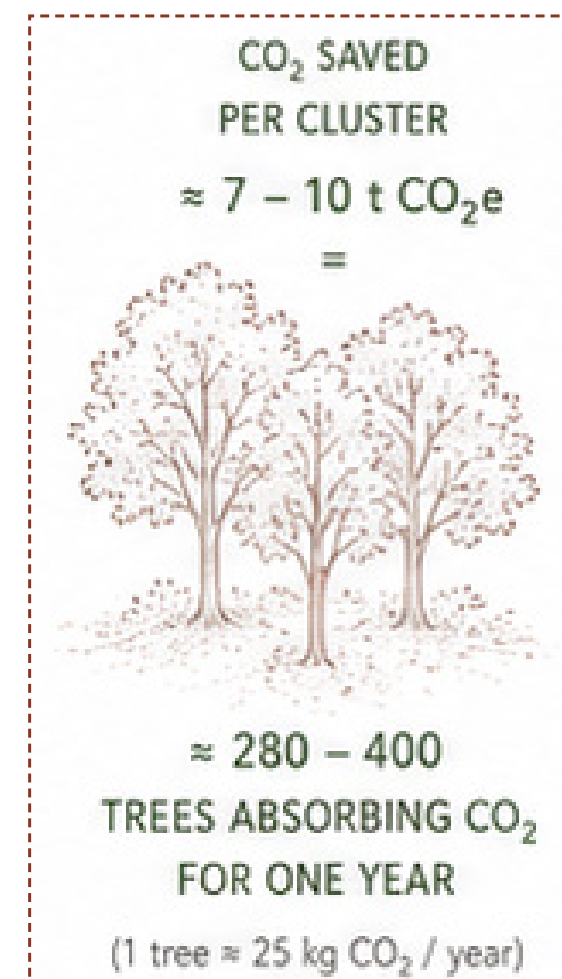


3. Use of materials

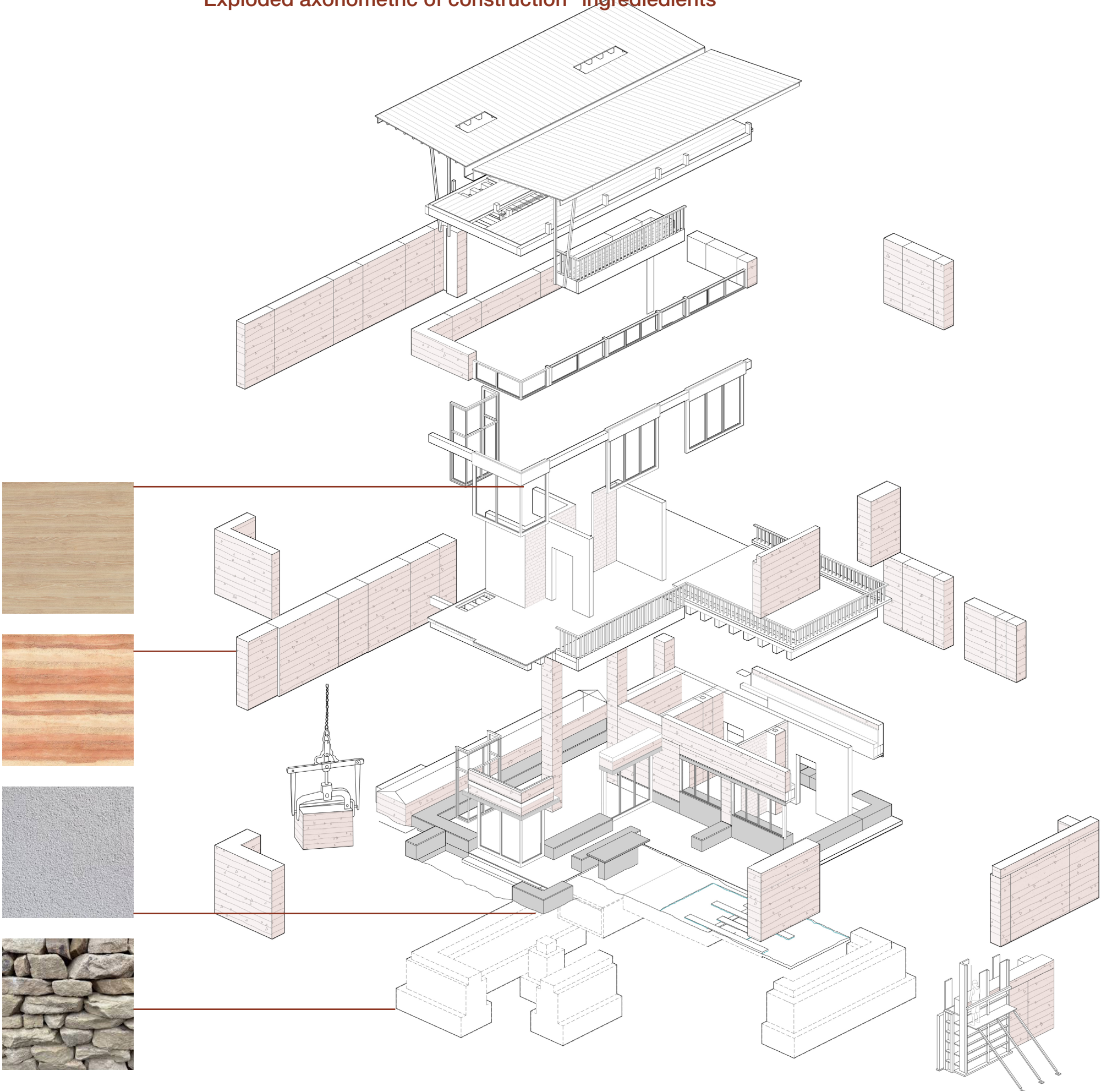


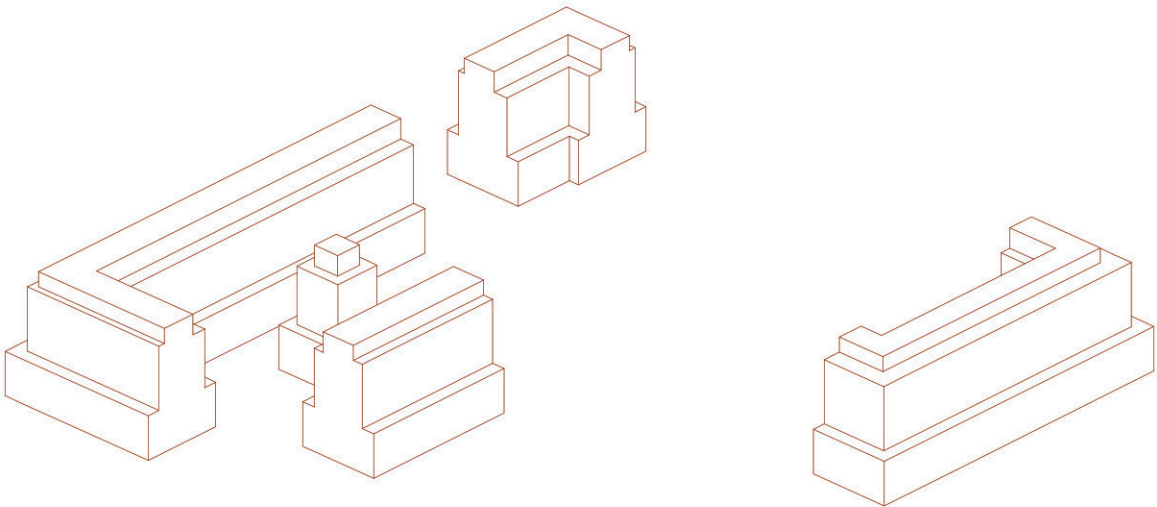
4. Energy and CO₂ emission per cluster

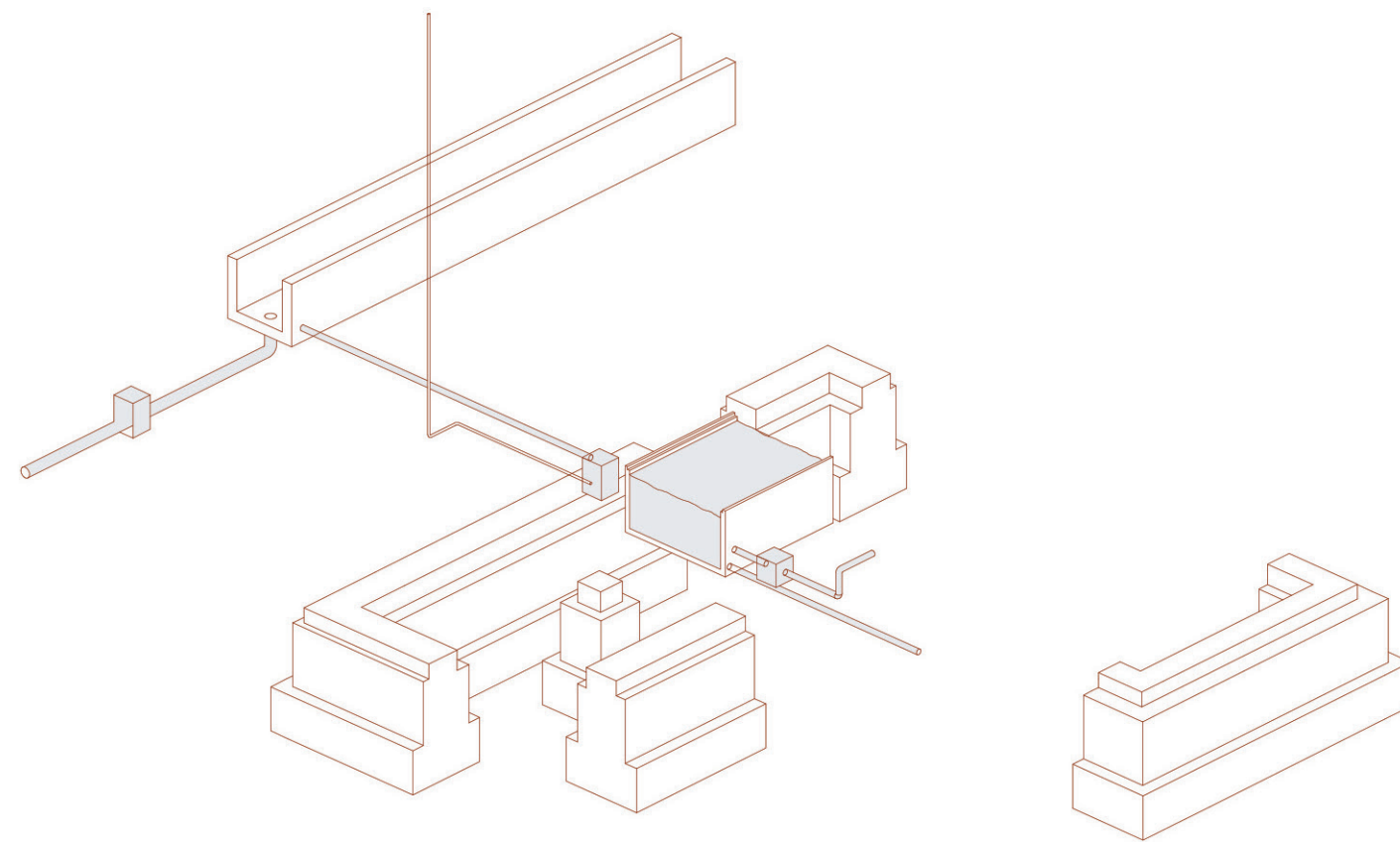
CONVENTIONAL (BASELINE)	PROPOSED SOLUTION
Portland cement concrete (≈ 30 m ³) 9 – 12 t CO ₂ e	Local stabilized rammed earth (≈ 30 m ³) 1 – 3 t CO ₂ e
Conventional water supply (pumped + treated) High energy demand	Desalination (solar powered) + rain / greywater reuse Low energy demand
TOTAL ≈ High CO₂ emissions High embodied energy	TOTAL ≈ 7 – 10 t CO₂e SAVED Lower embodied energy

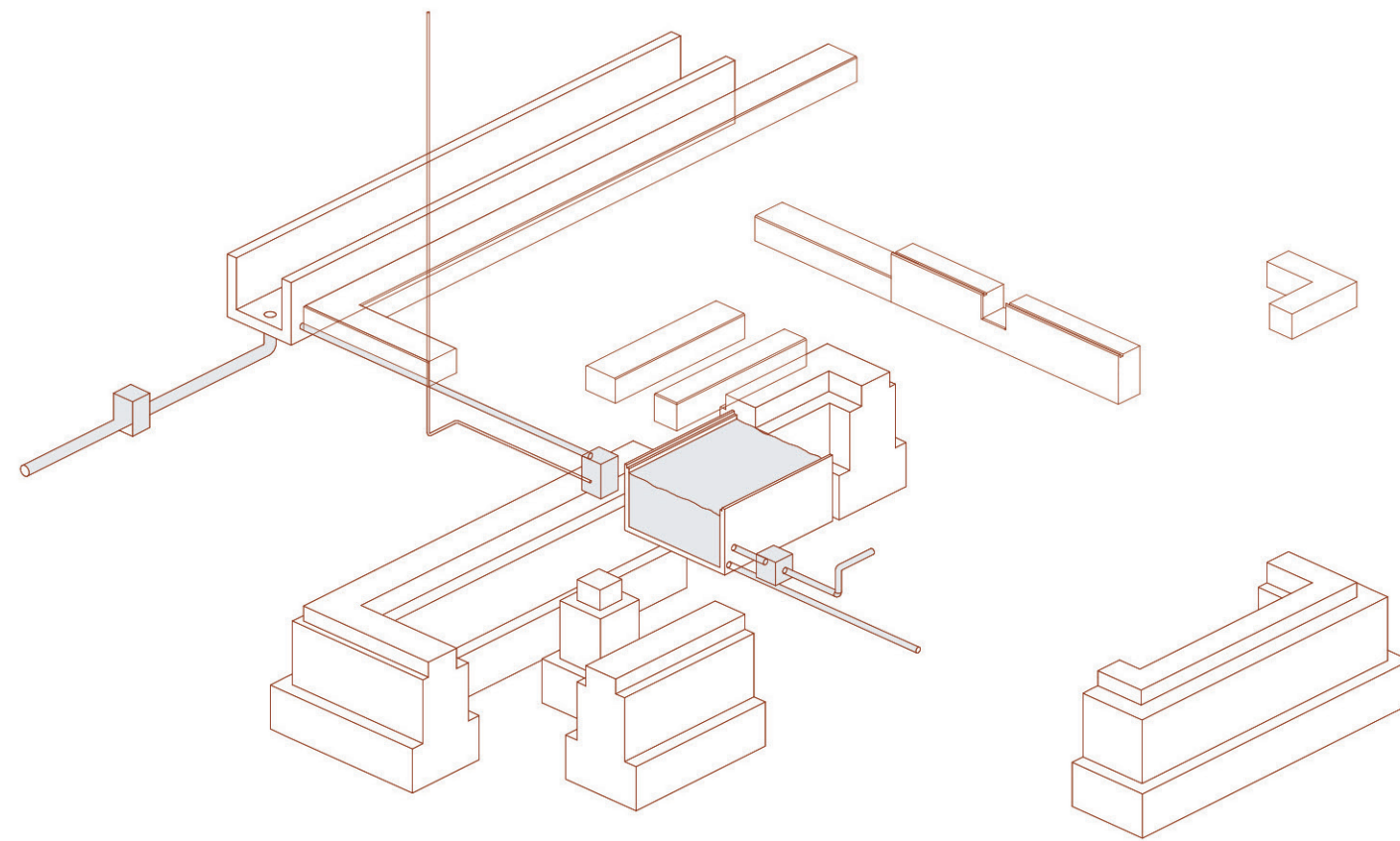


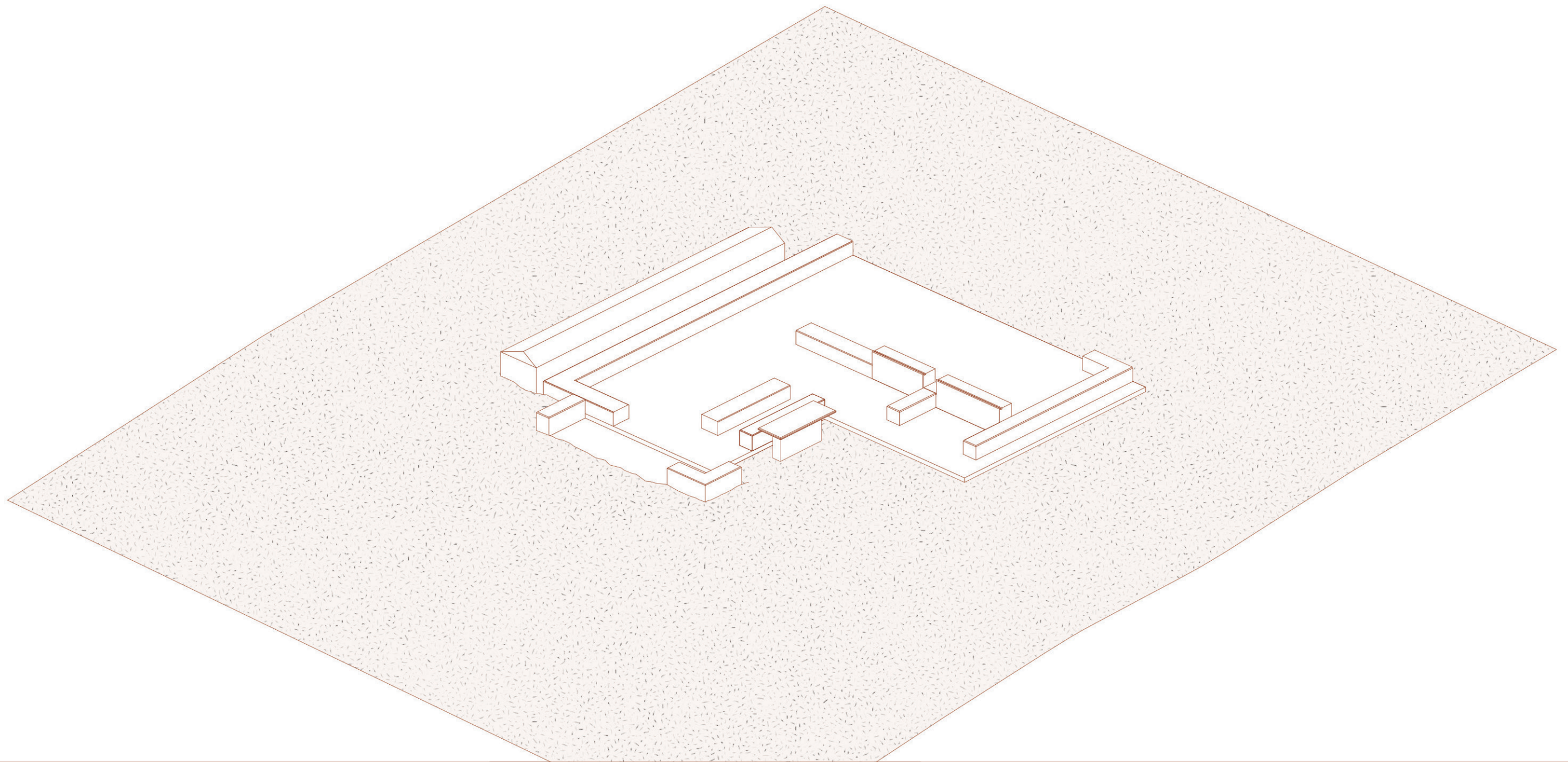
Exploded axonometric of construction “ingrediedients”

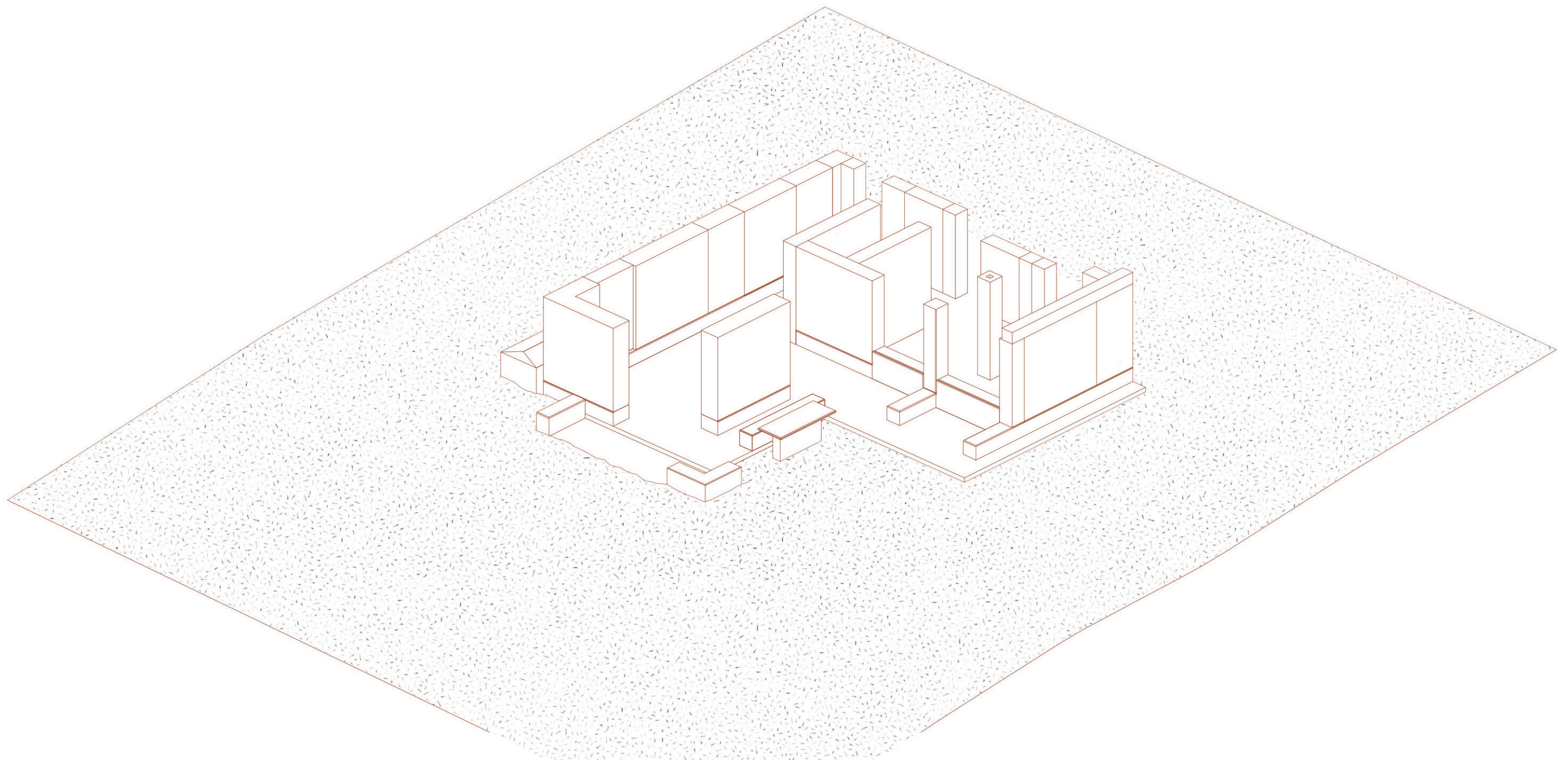


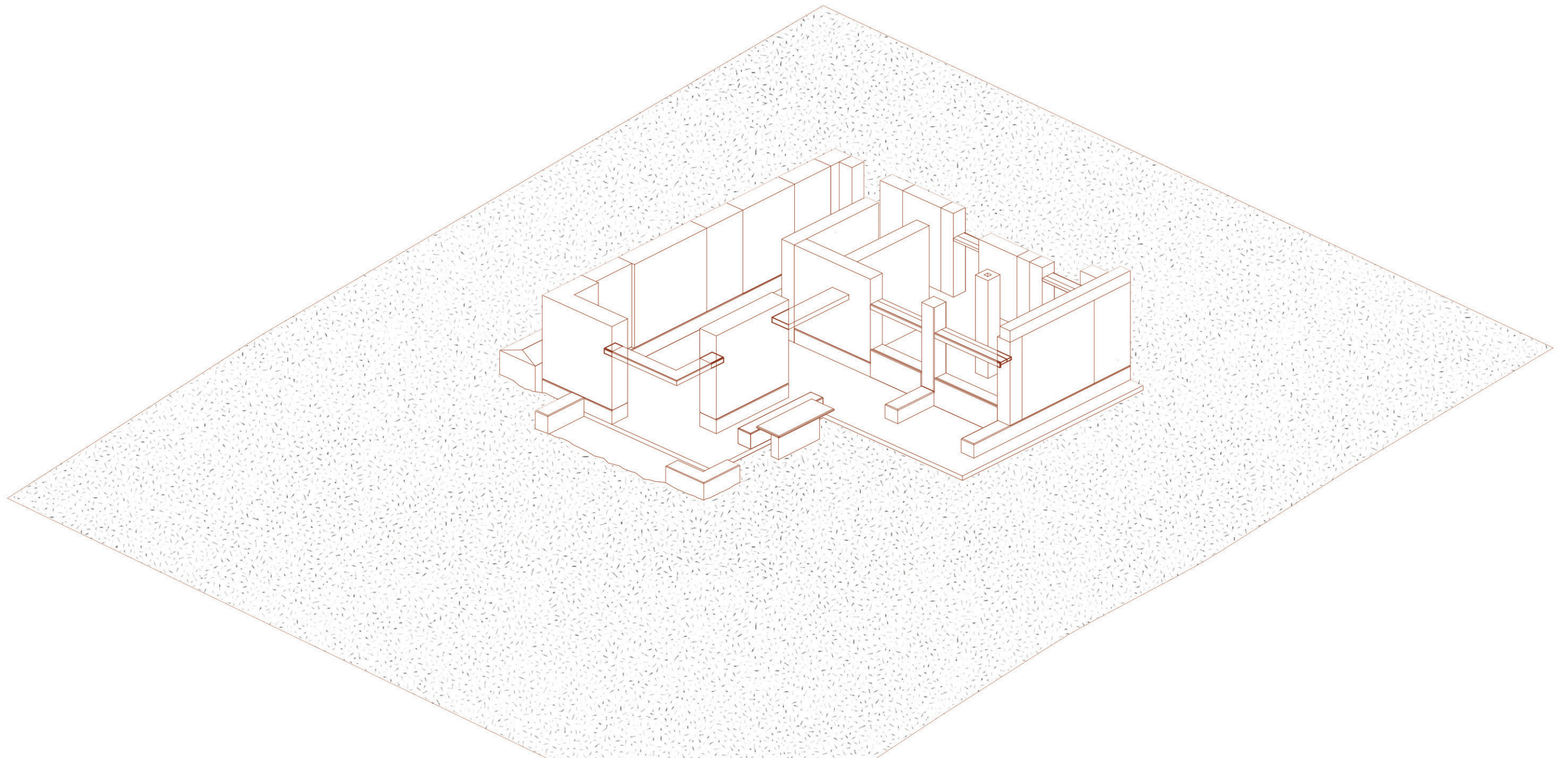


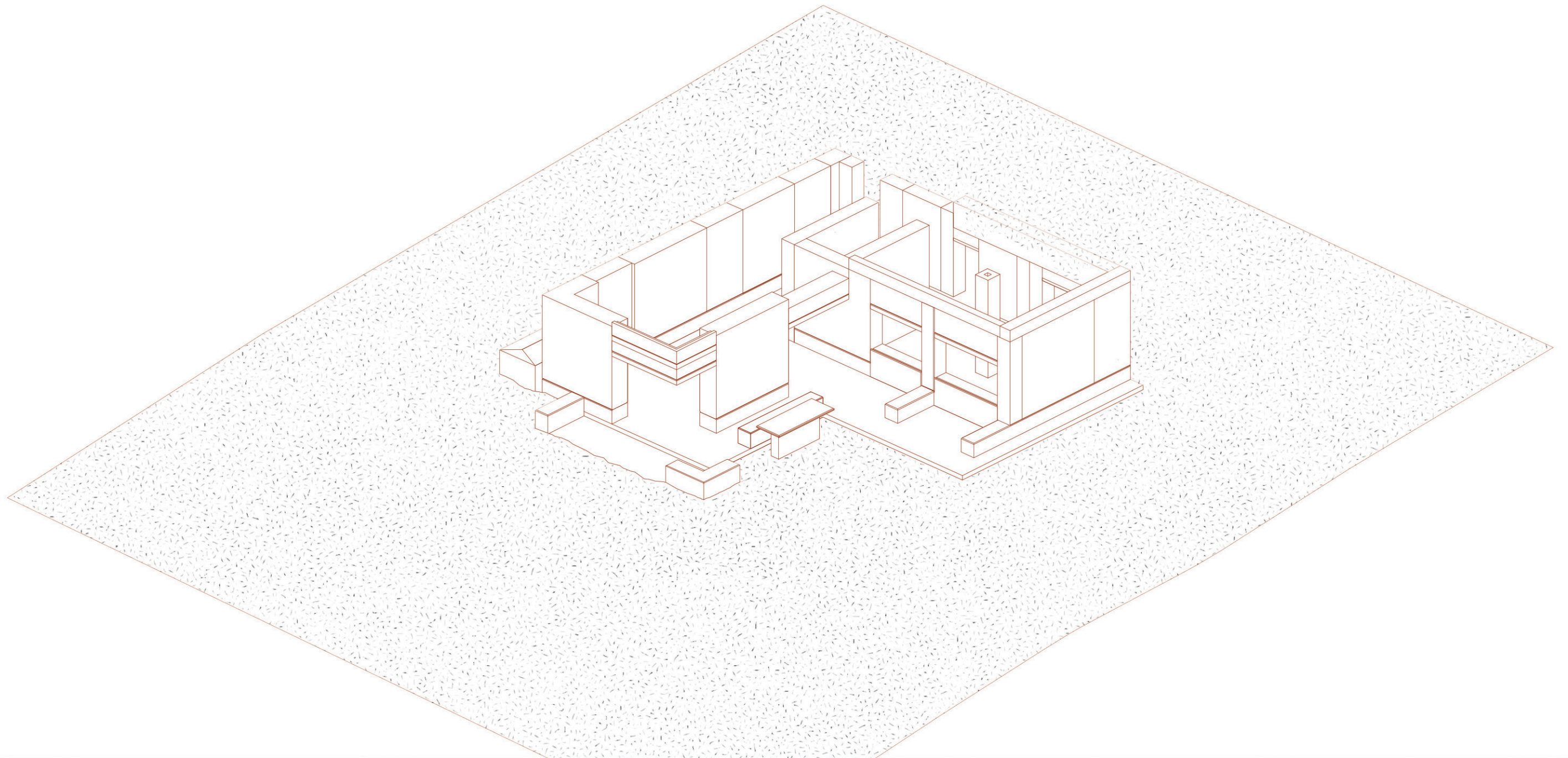


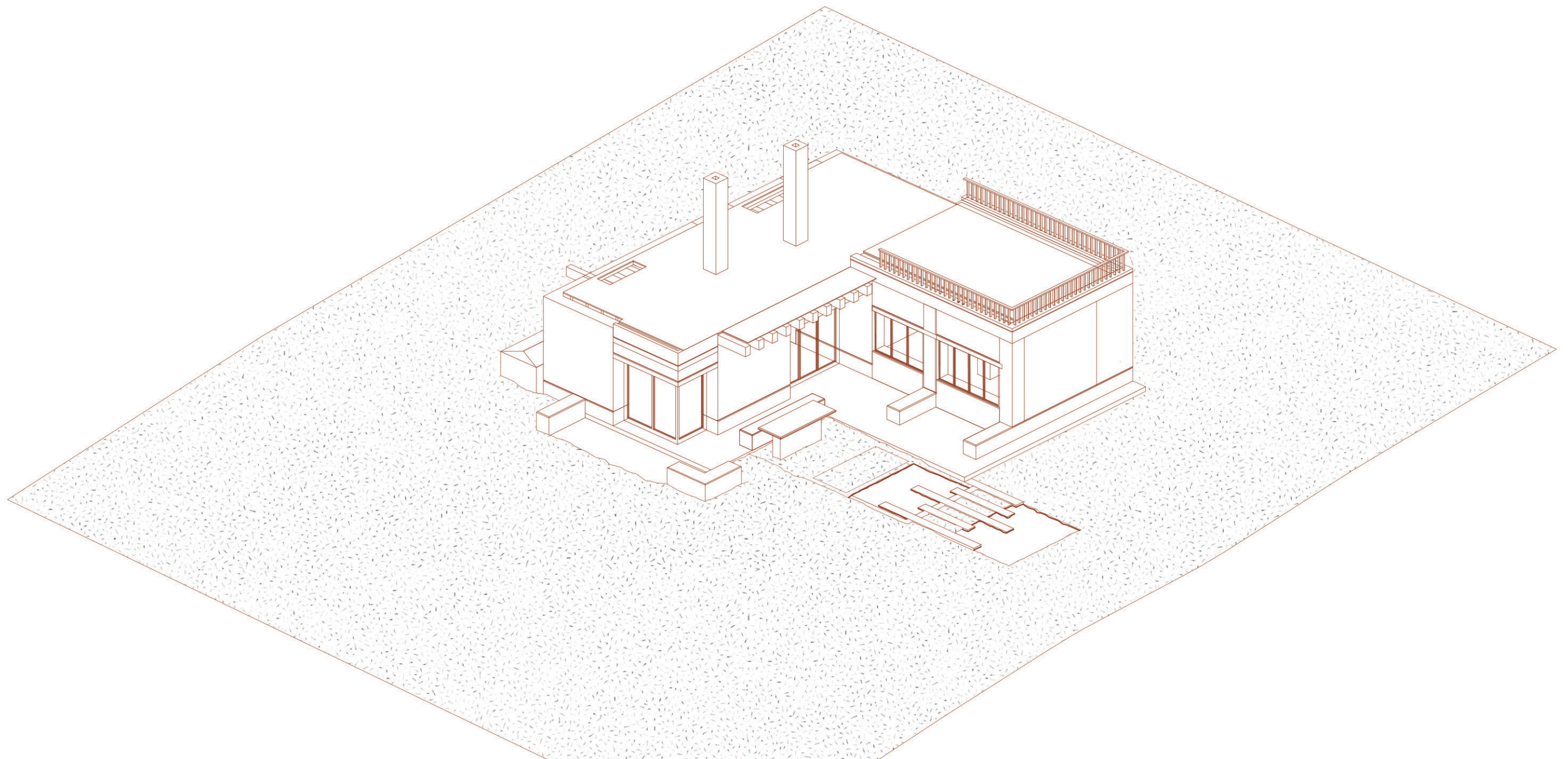


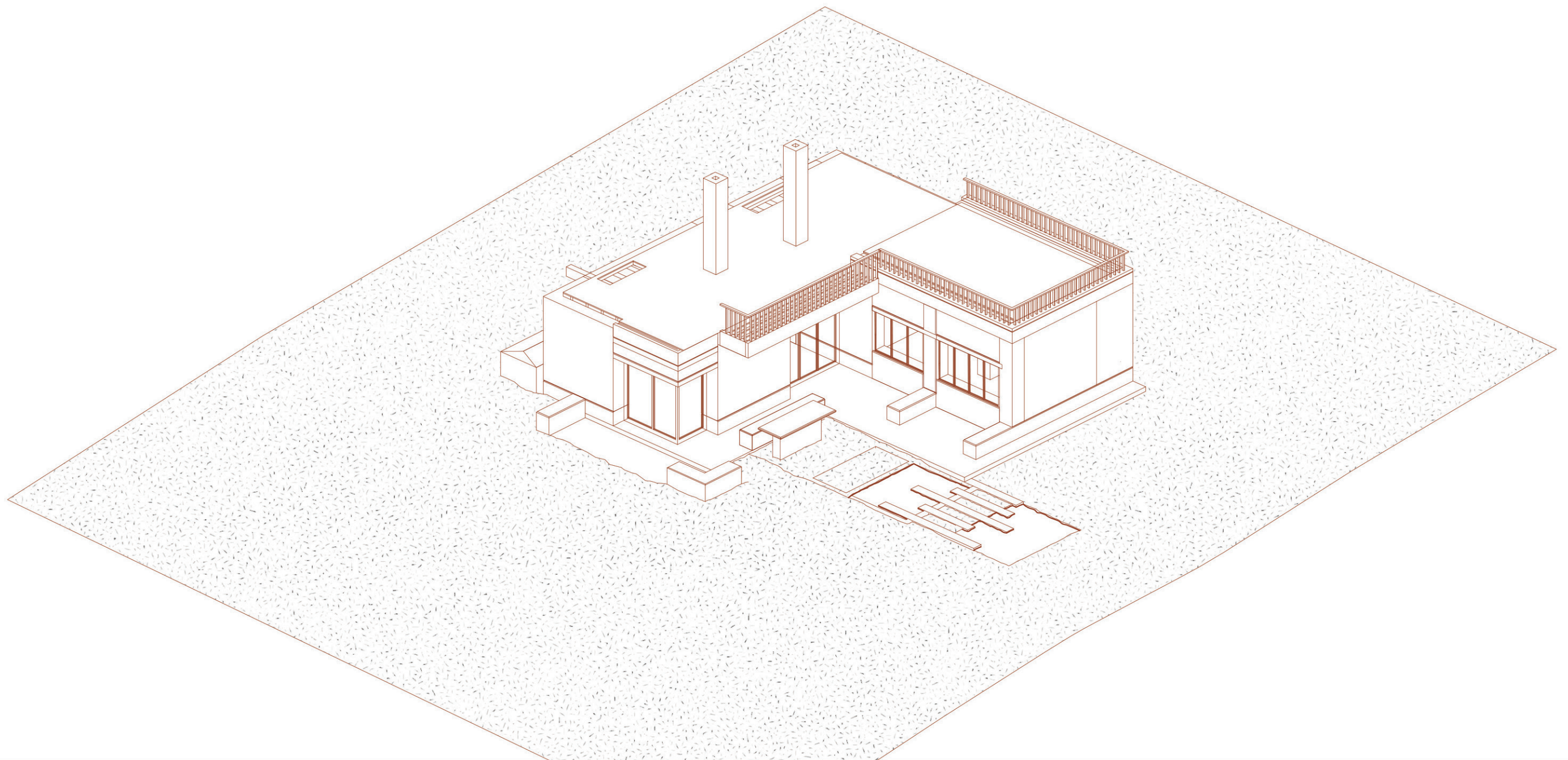


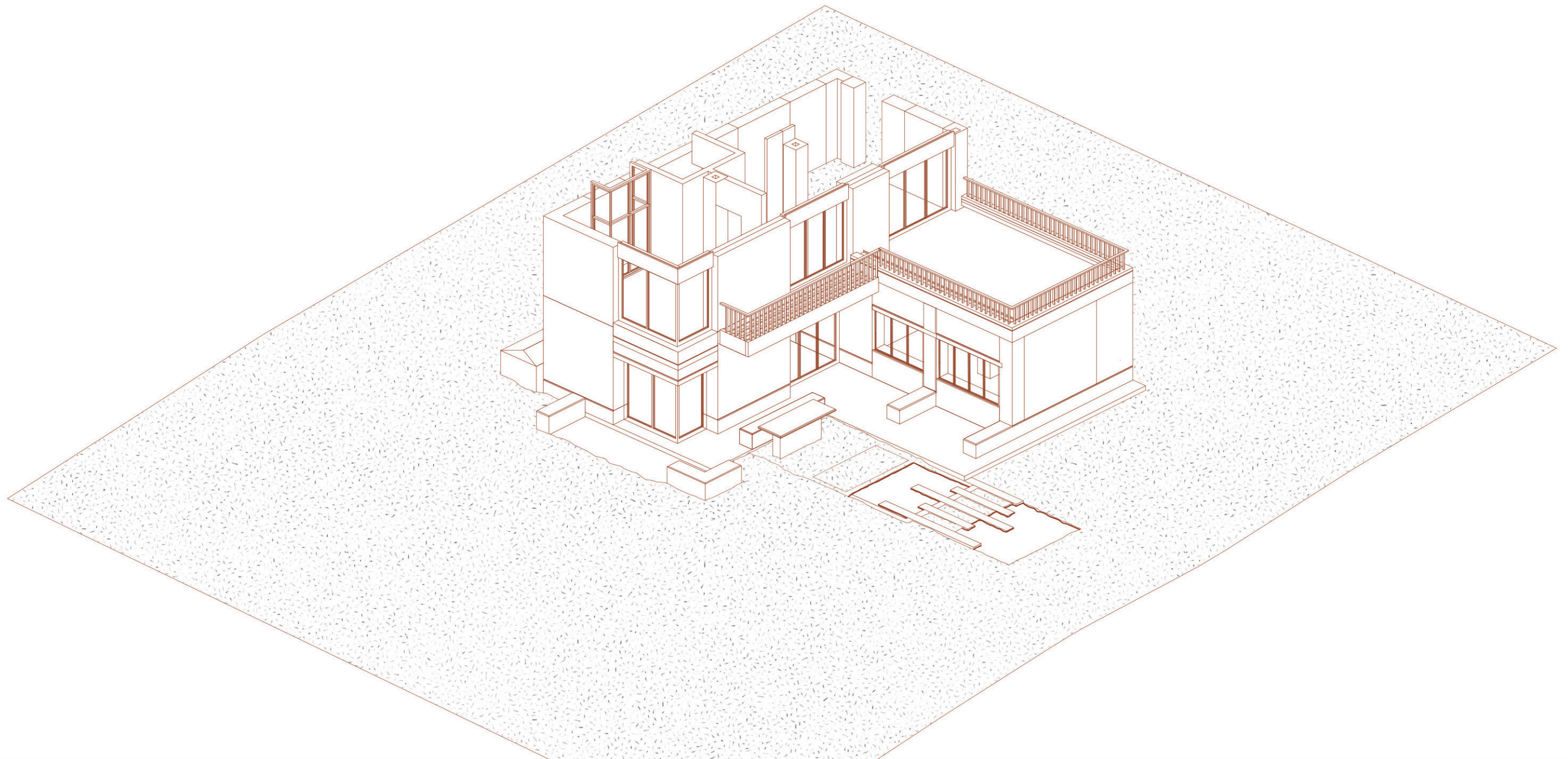


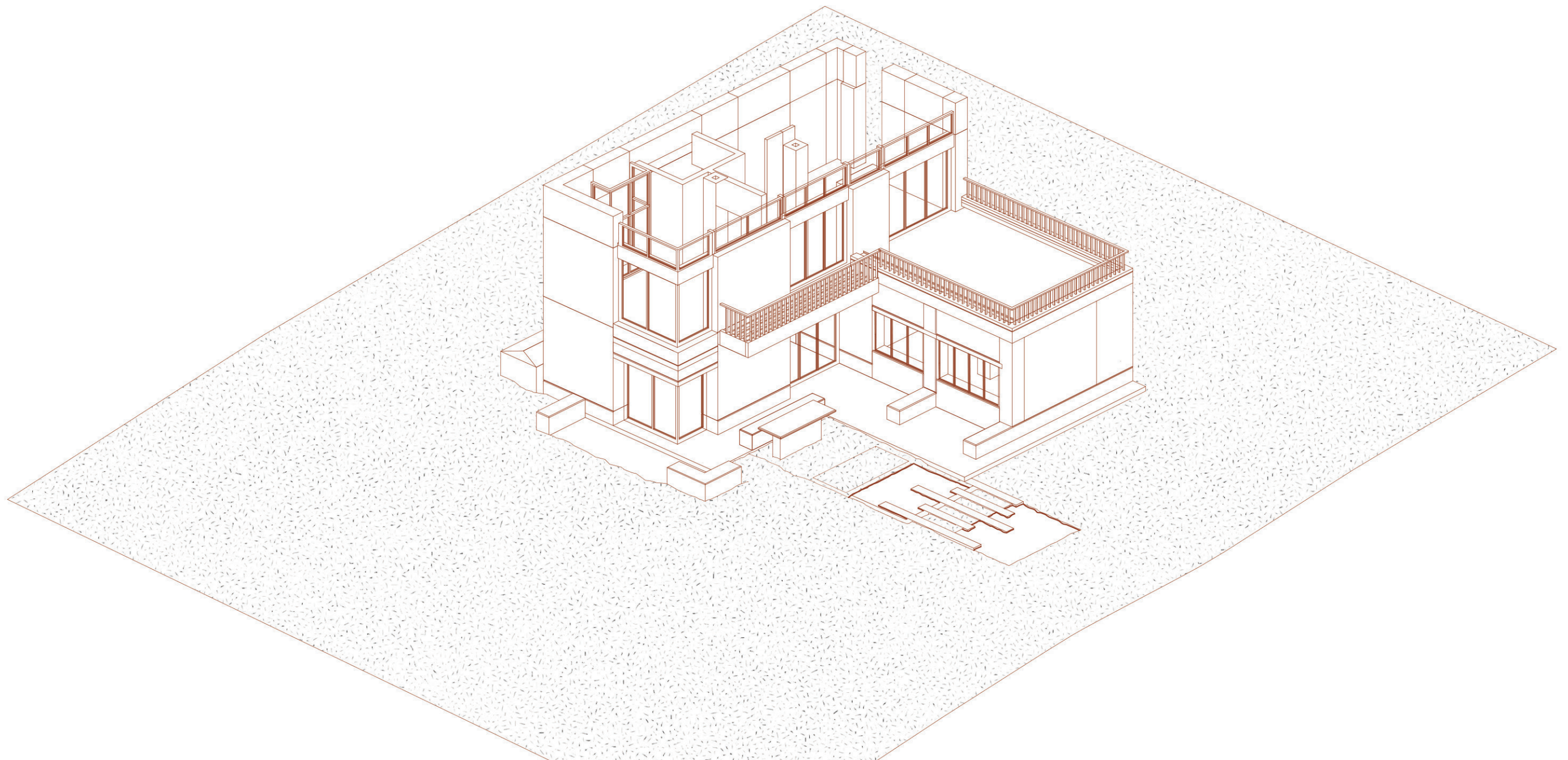


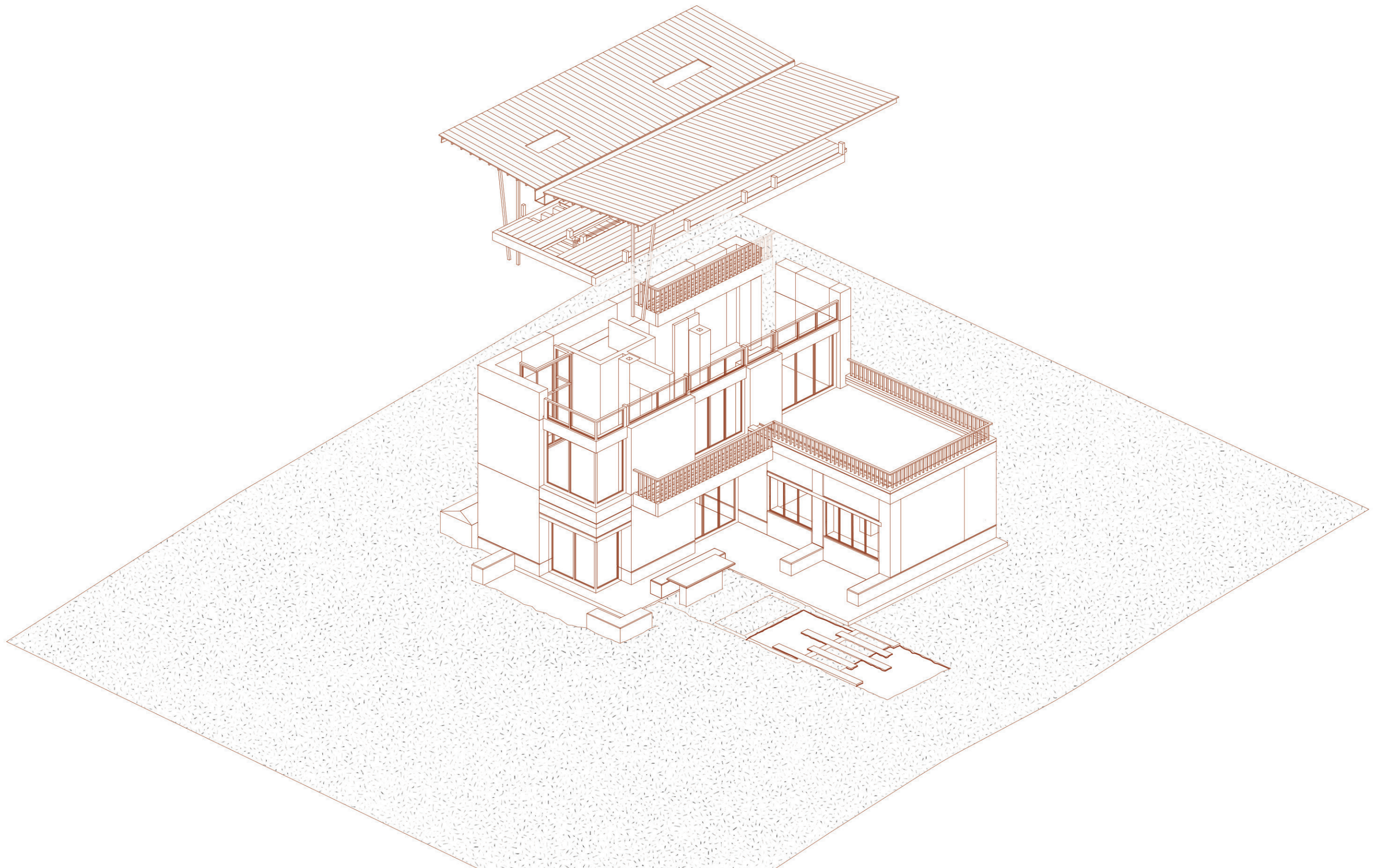


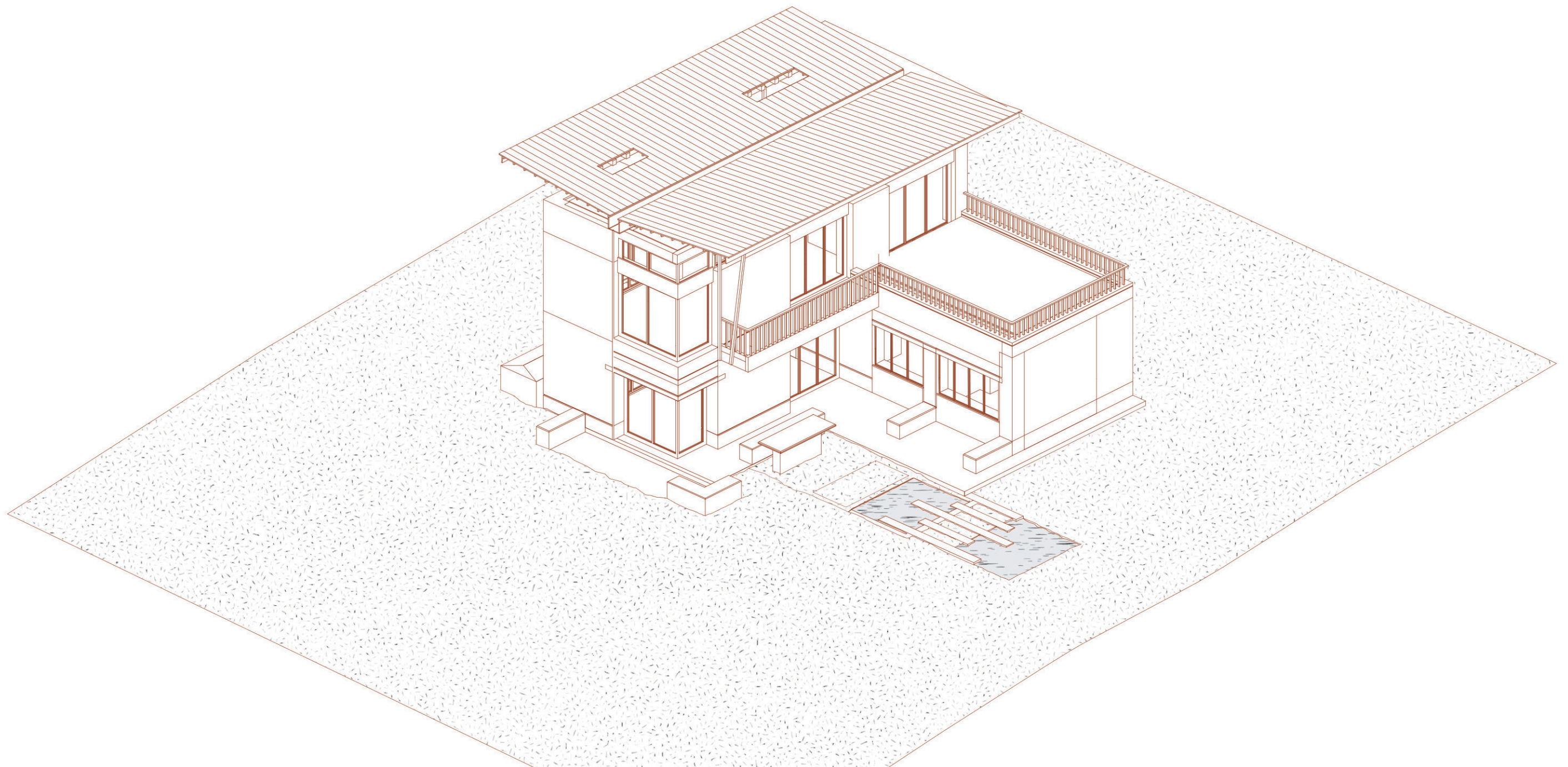












Conclusions

Conclusions

water and material
regulation



climate
regulation

Conclusions

water and material
regulation



climate
regulation

desalination



water autonomy

Conclusions

water and material
regulation



climate
regulation

desalination

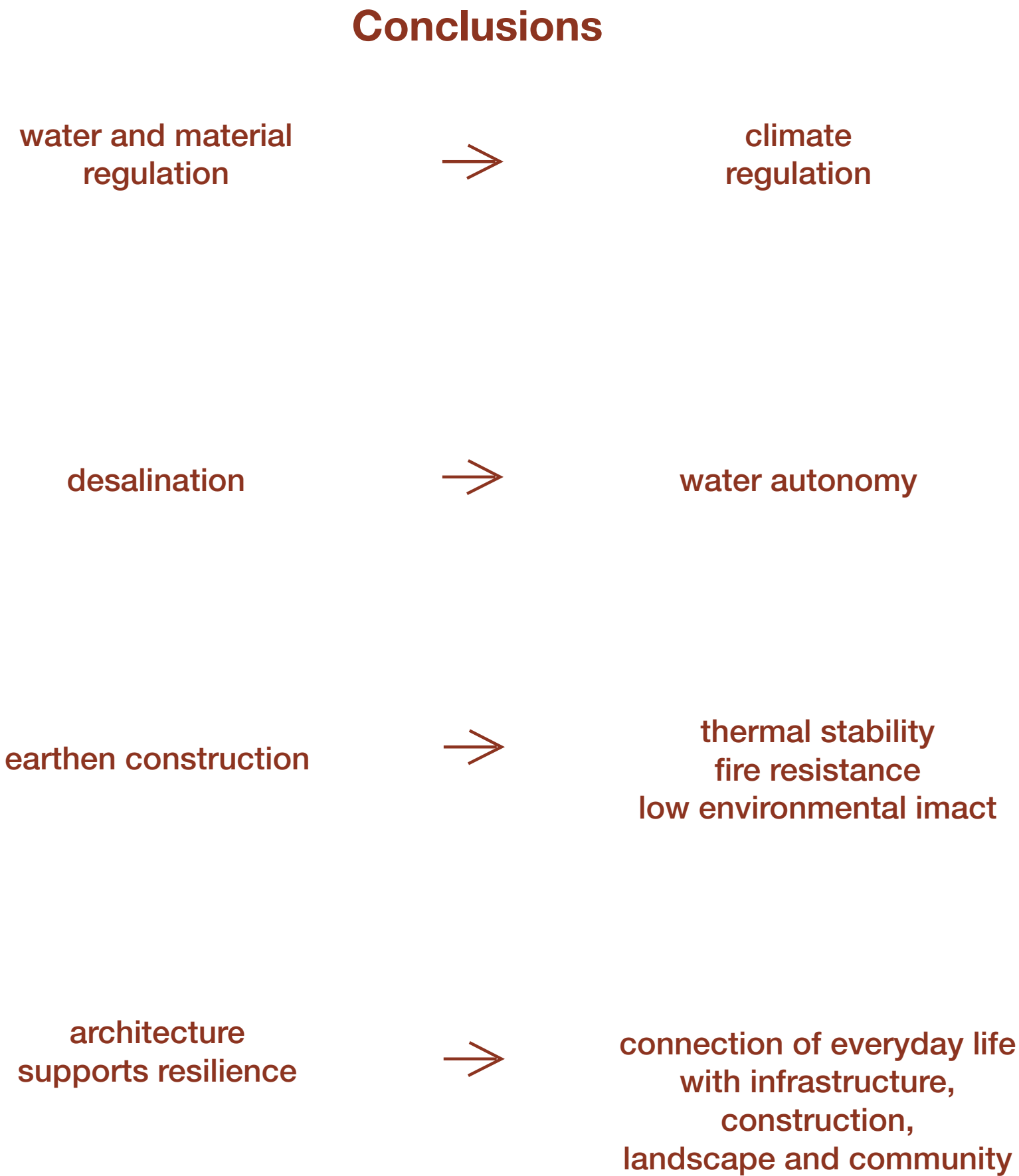


water autonomy

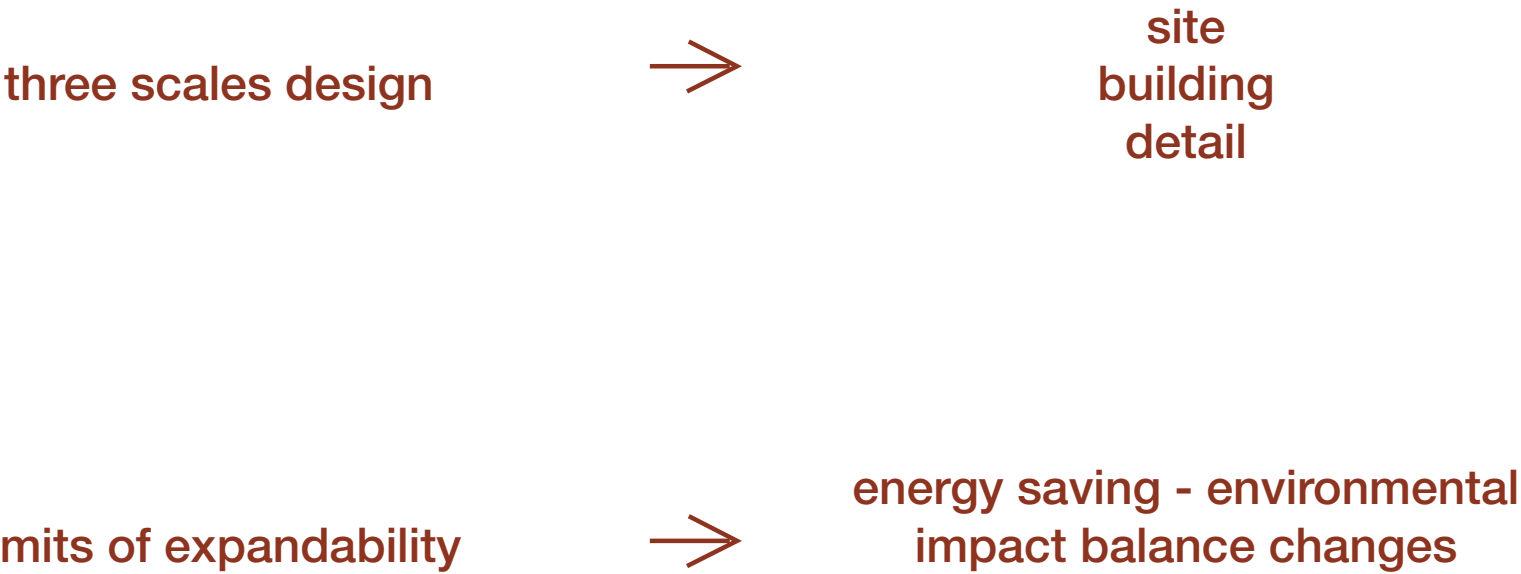
earthen construction



thermal stability
fire resistance
low environmental imact



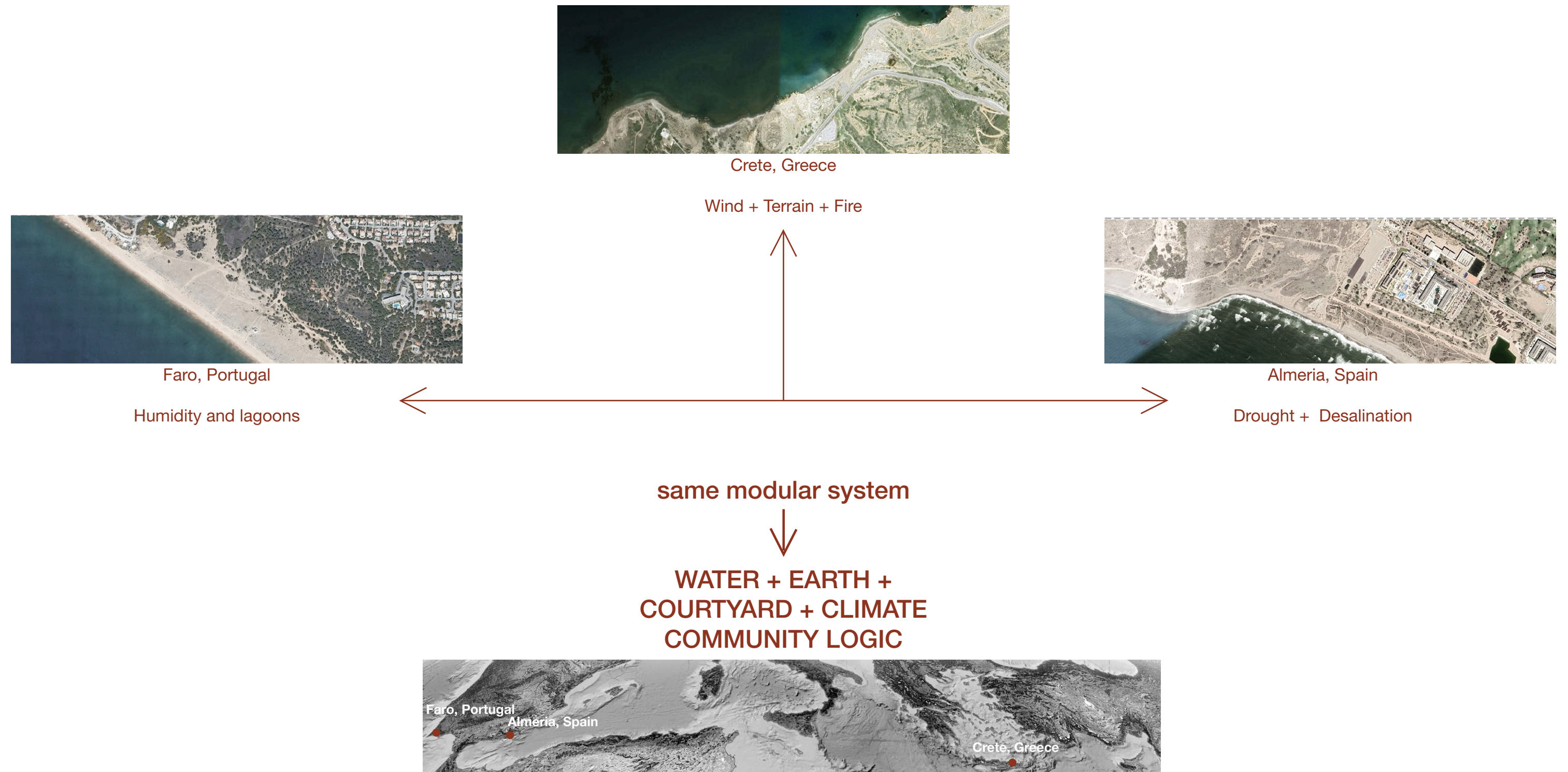
Reflections



relation to food waste of Almeria's green houses

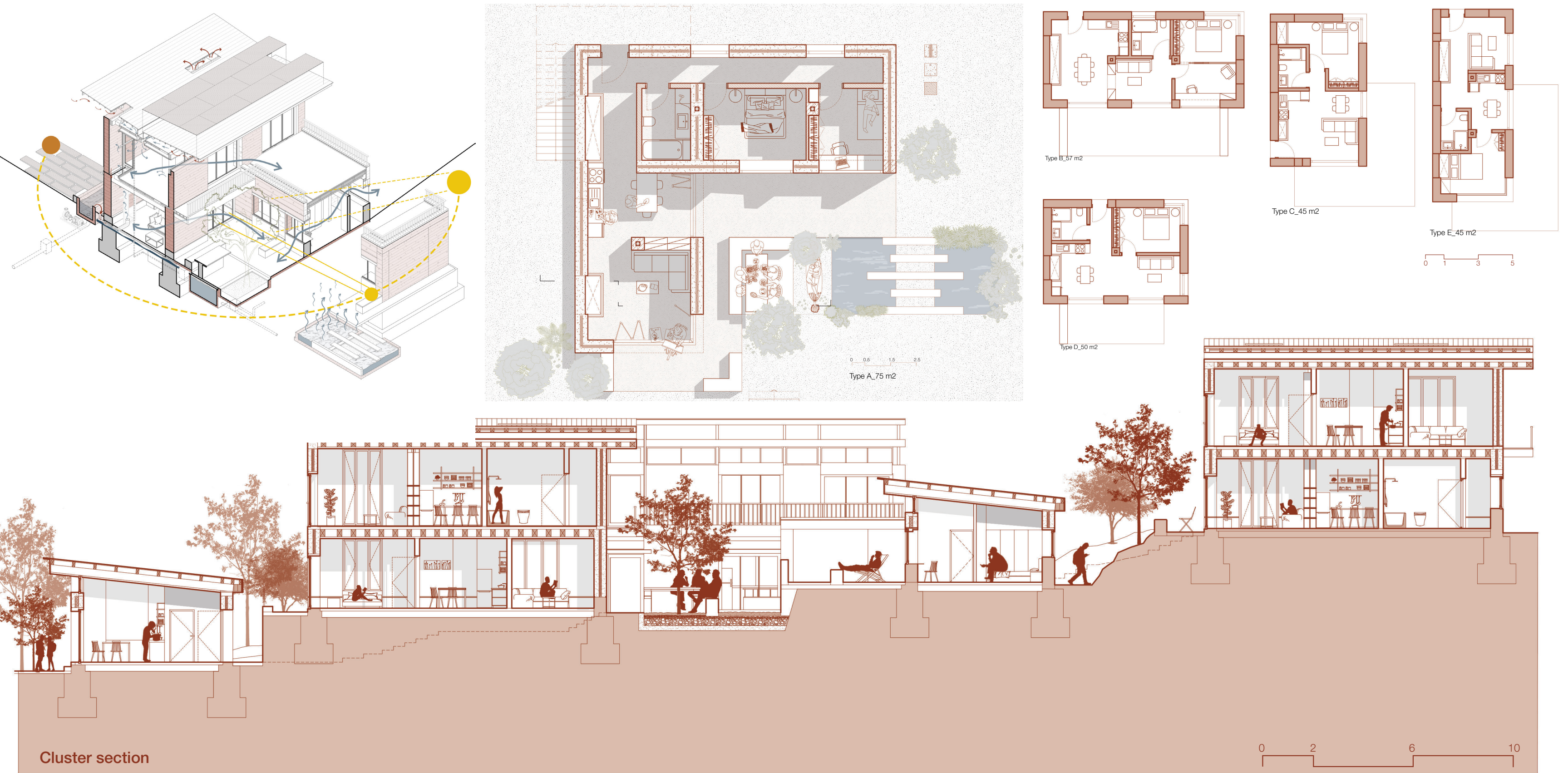
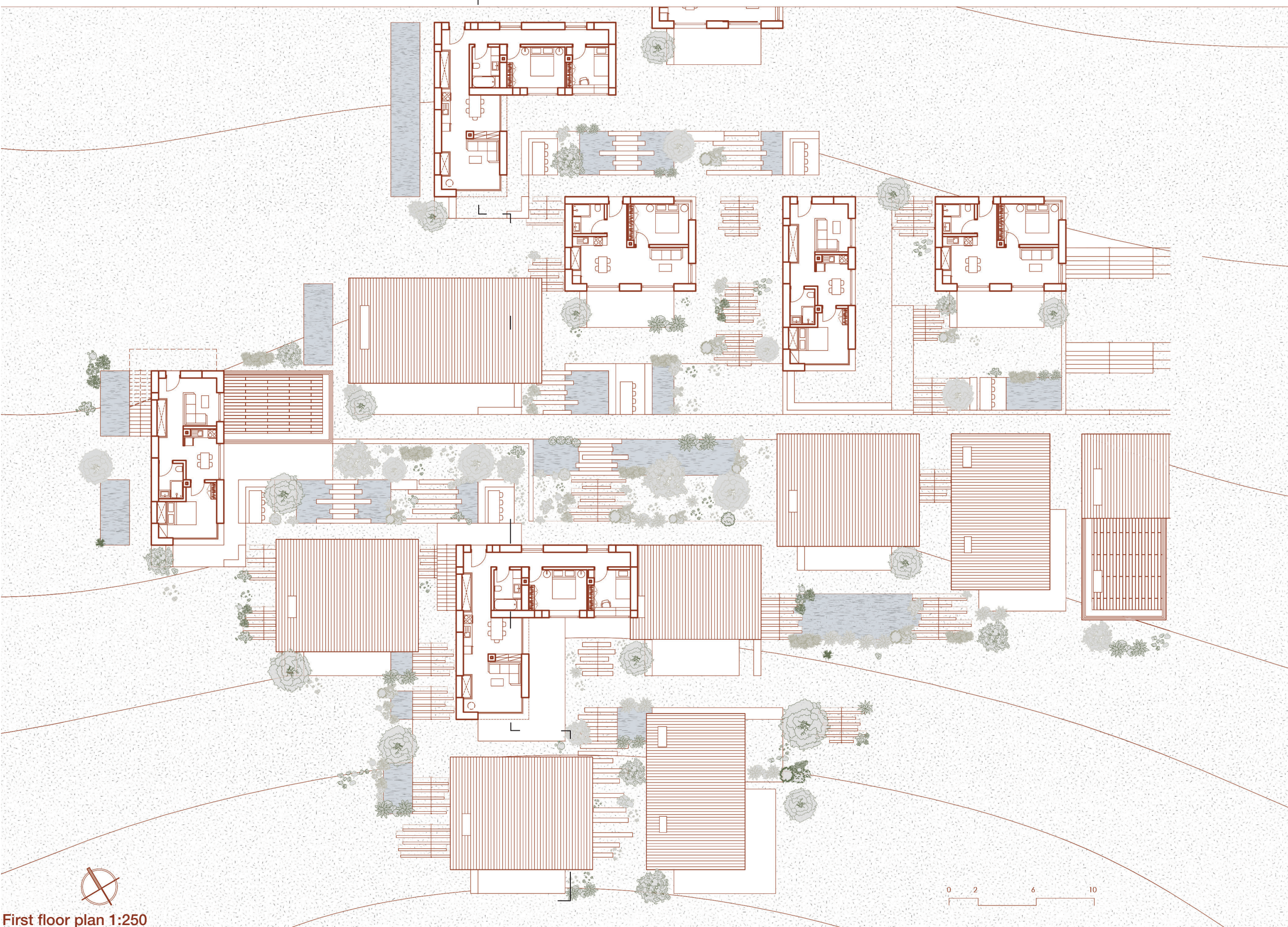
Reflections

How can a place-responsive modular architectural system, grounded in earthen materiality and layered system design, enhance climate resilience in Mediterranean coastal settlements facing water scarcity and wildfire risk?



Thank you!

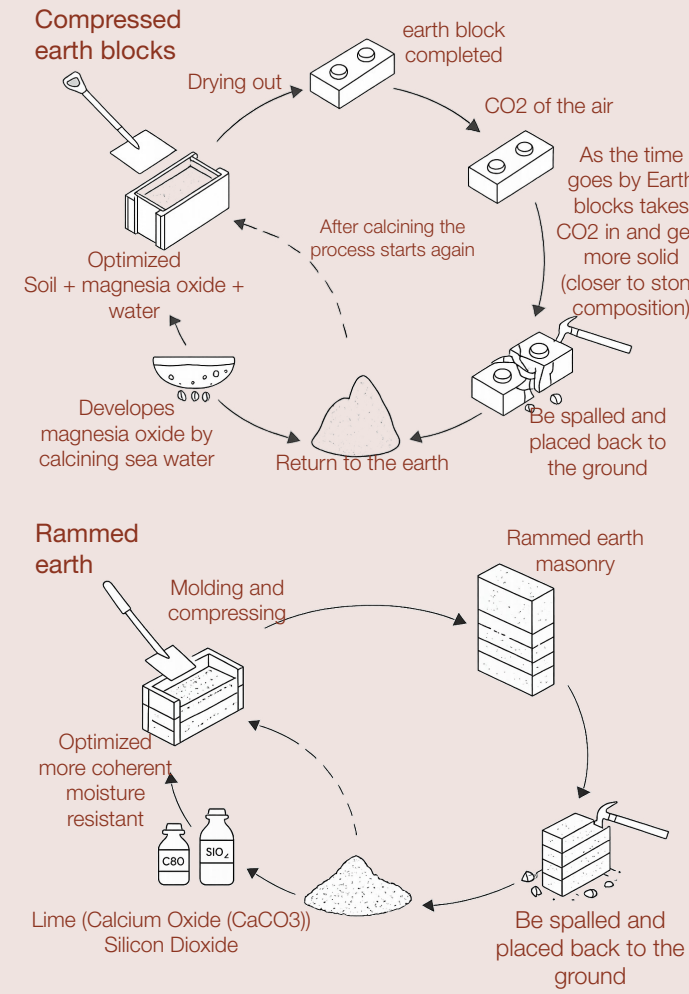




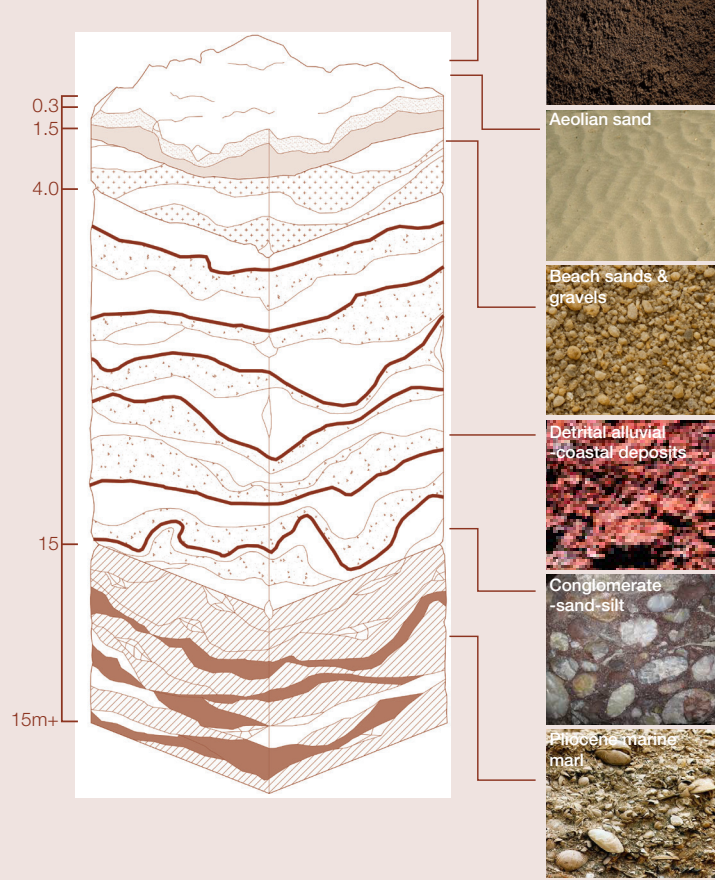
Material | Construction study

Earthen Materials	Structural capacity	Fire behaviour	Moisture resistance	Thermal performance	Optimization Potential
Adobe		Non-combustible			High – lime and pozzolans improve strength and durability
Cob block		Non-combustible			Moderate – fiber and lime improve cohesion
Compressed earth blocks		Non-combustible			Very high – lime/ pozzolans improve strength & durability
Rammed earth		Non-combustible			Very high – lime/ pozzolans enhance resistance
Light clay		Non-combustible			Moderate – lime stabilization possible
Hempcrete		Low flame spread			Moderate – mineral binders essential

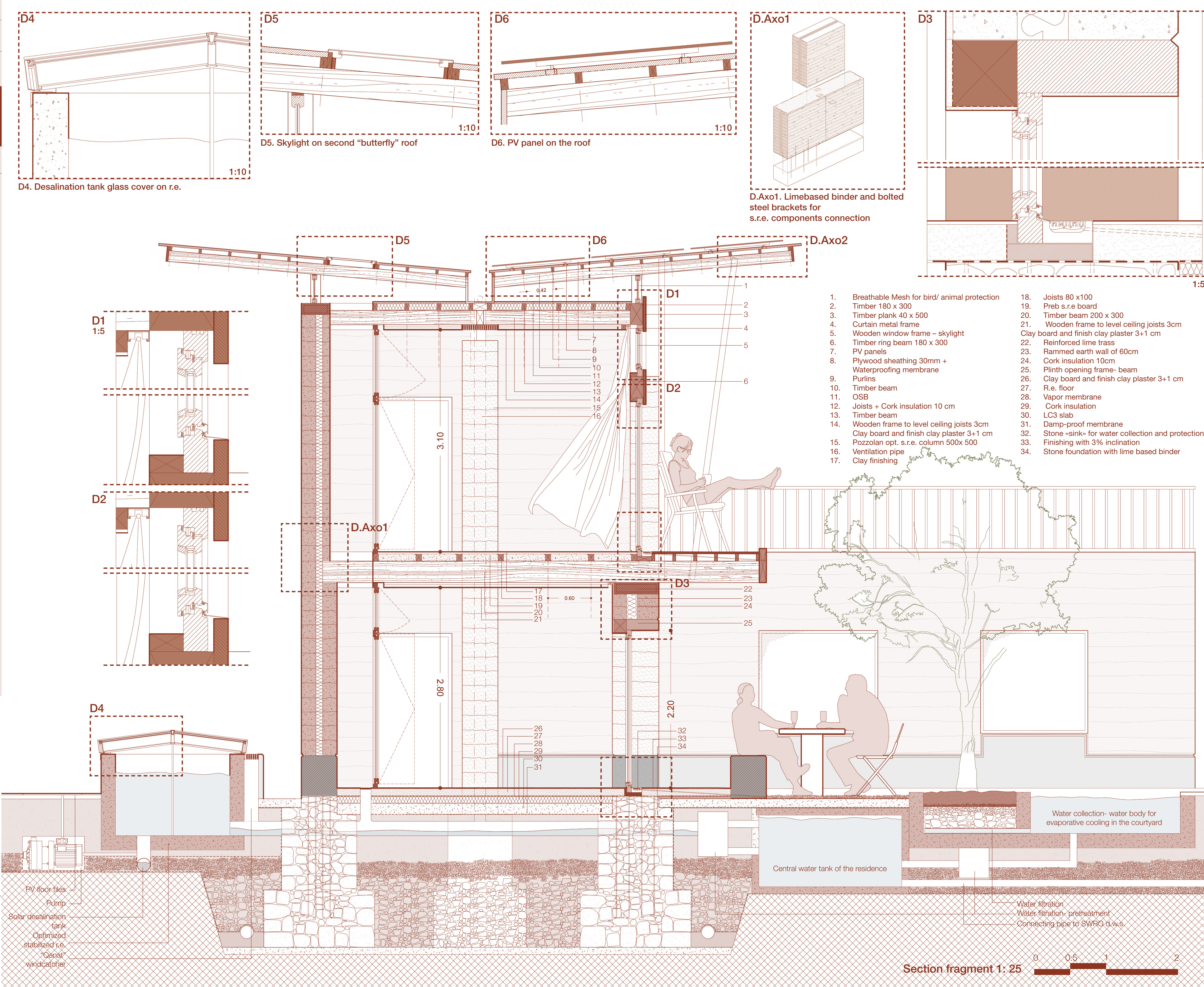
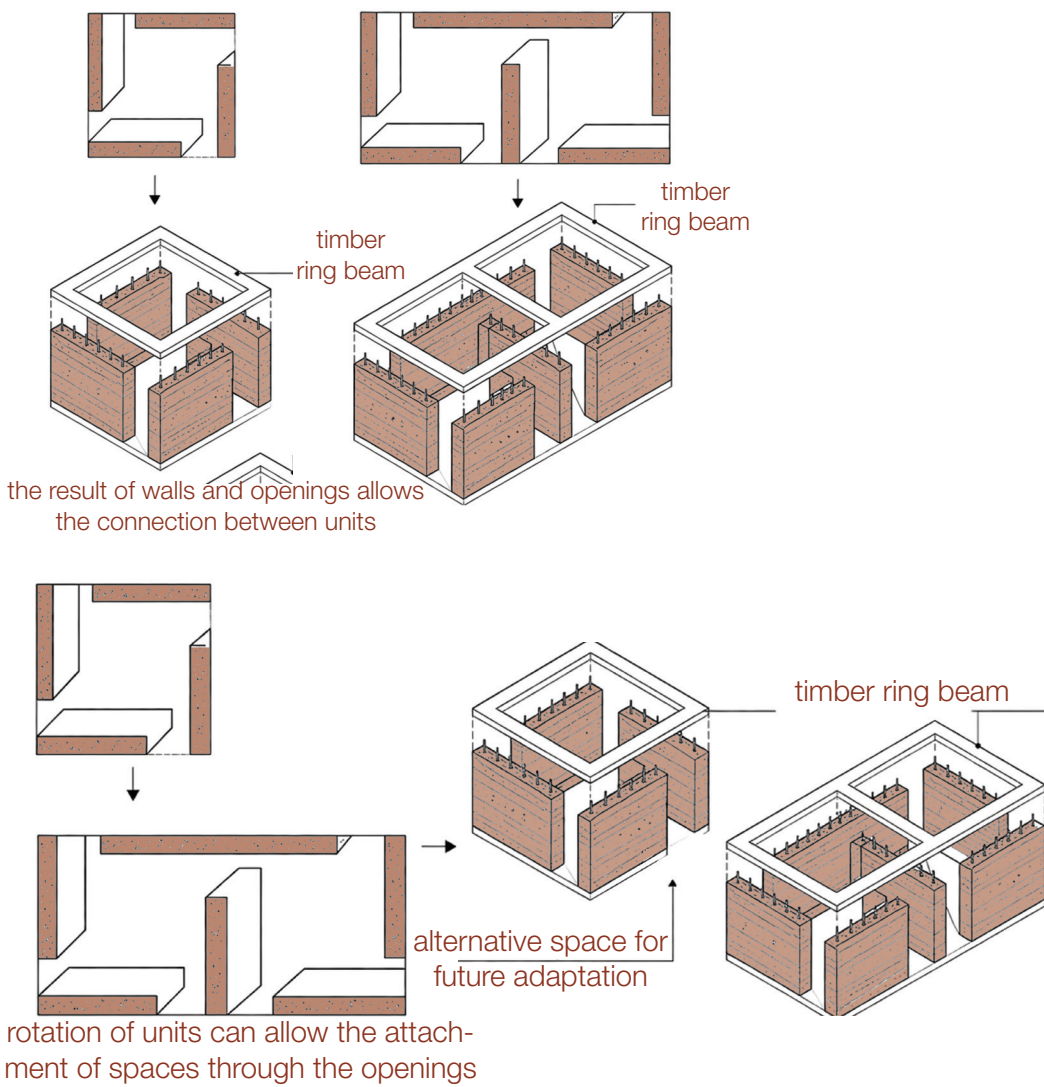
Material optimization

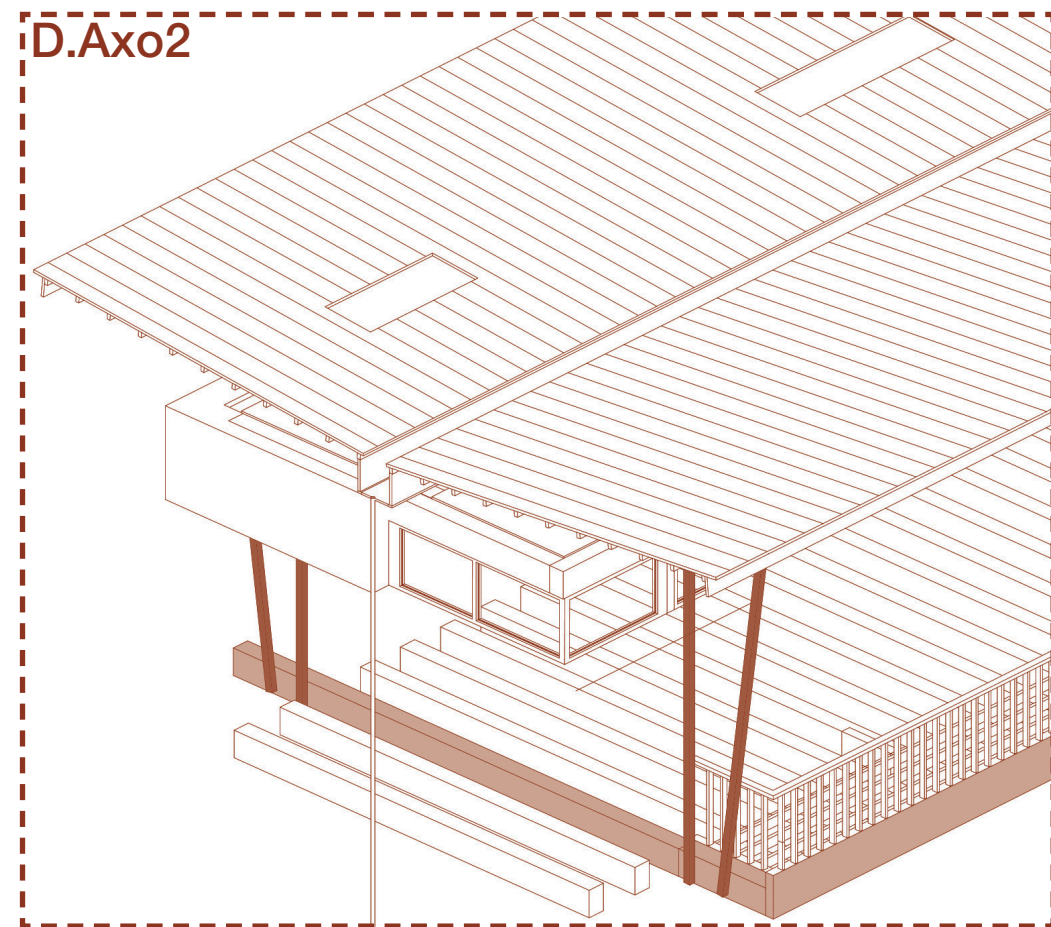


Locally available materials



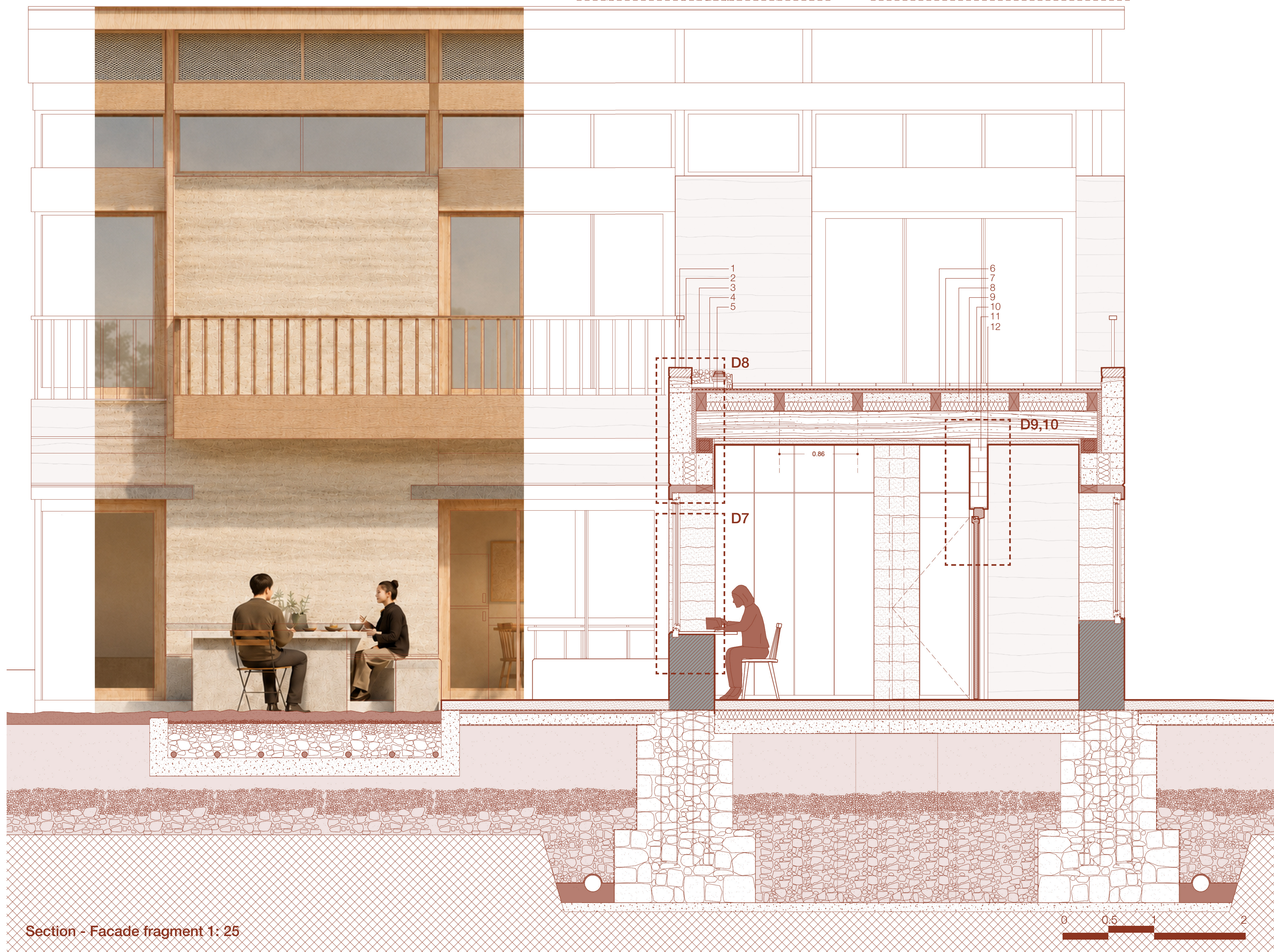
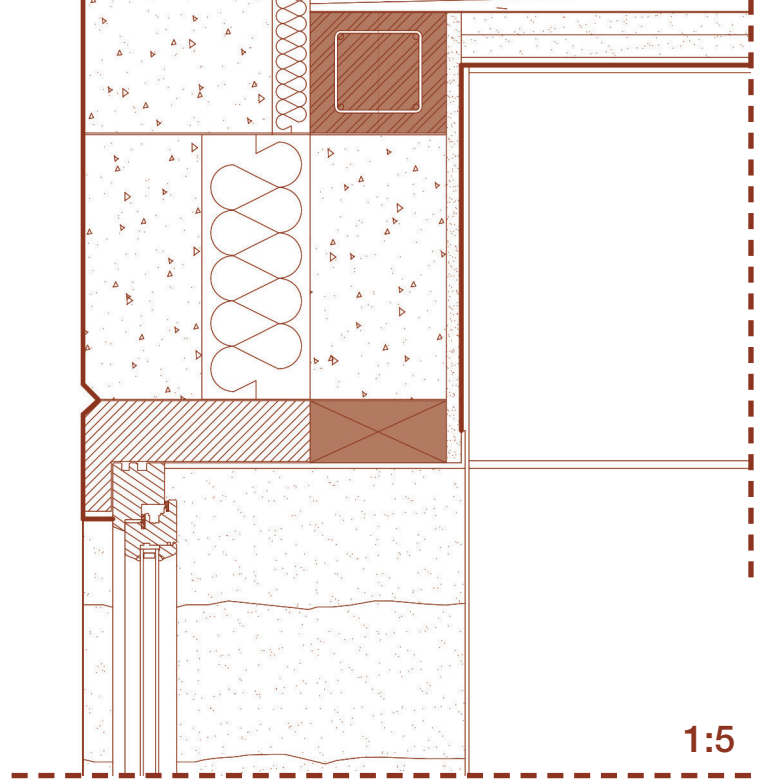
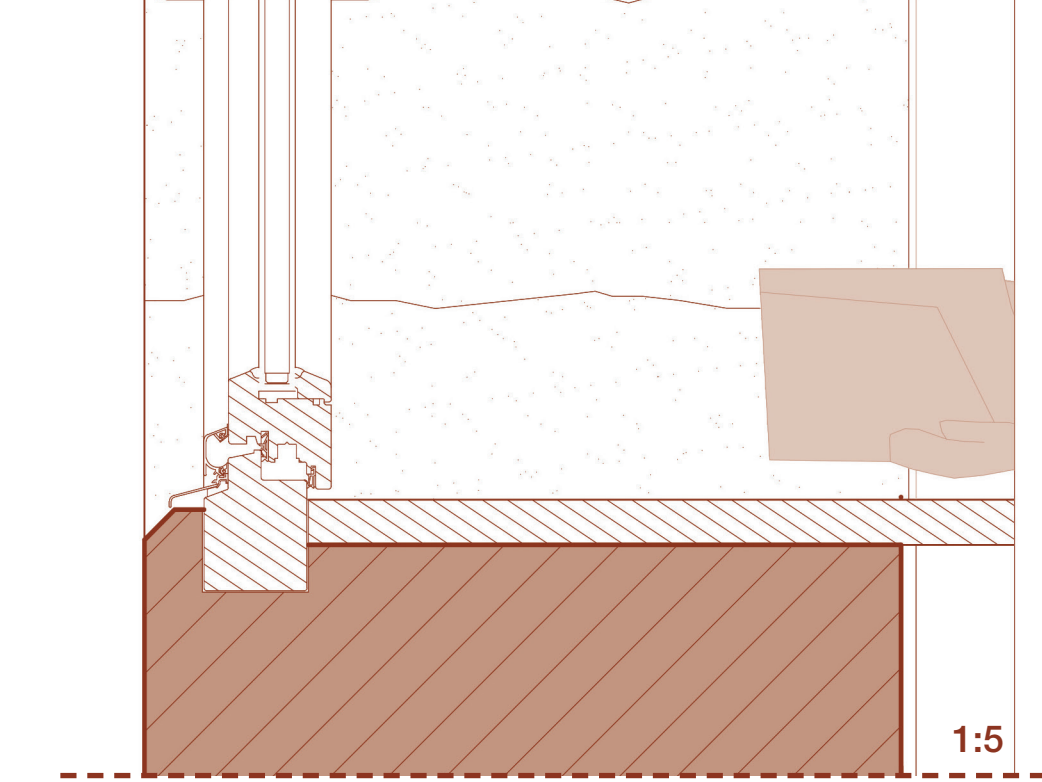
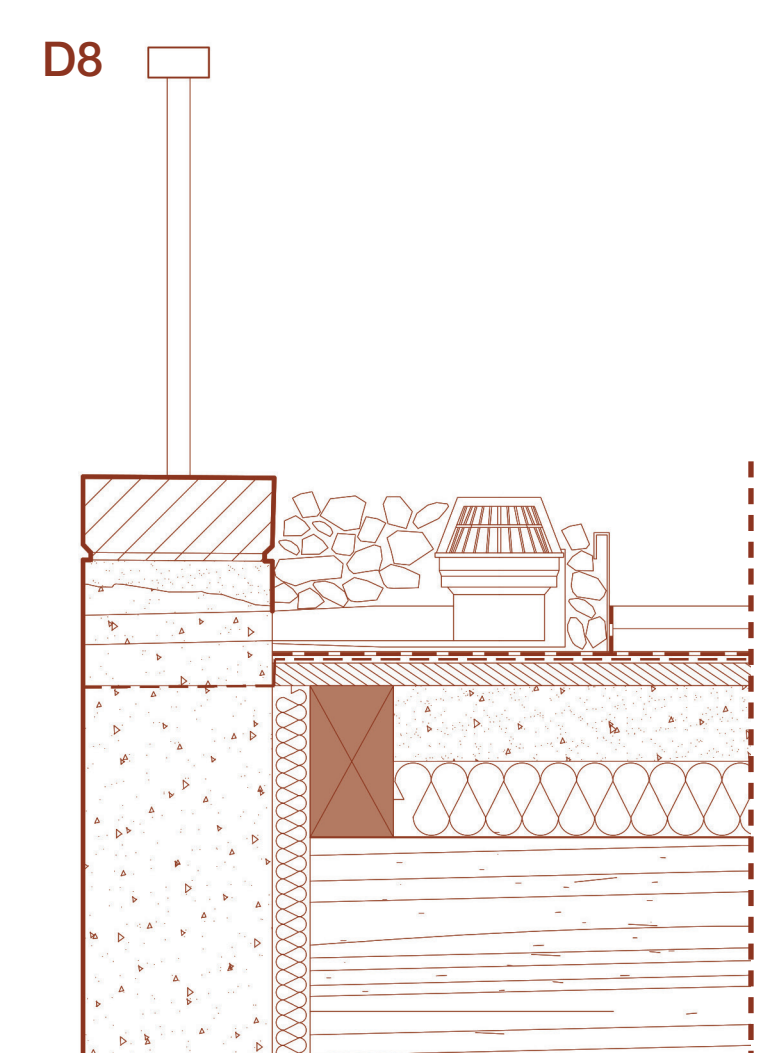
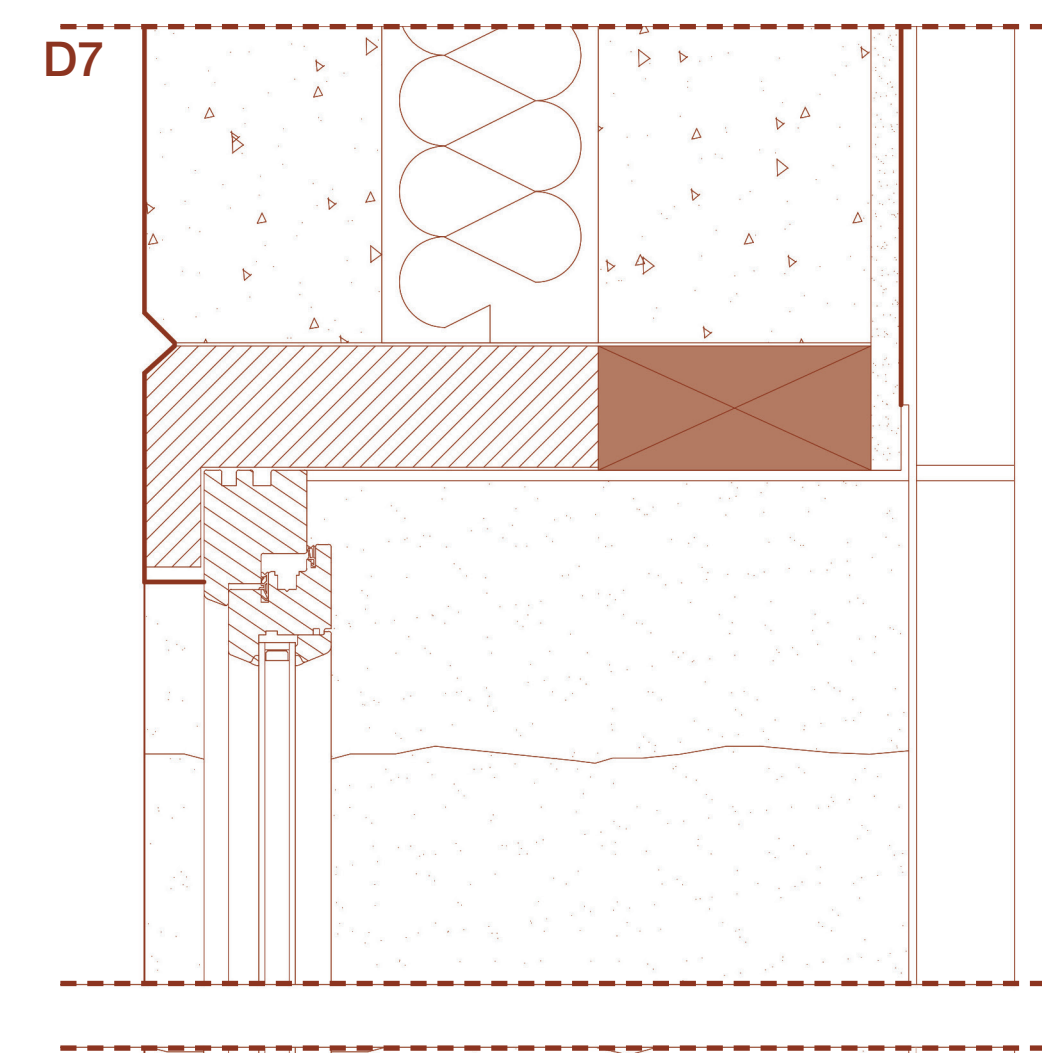
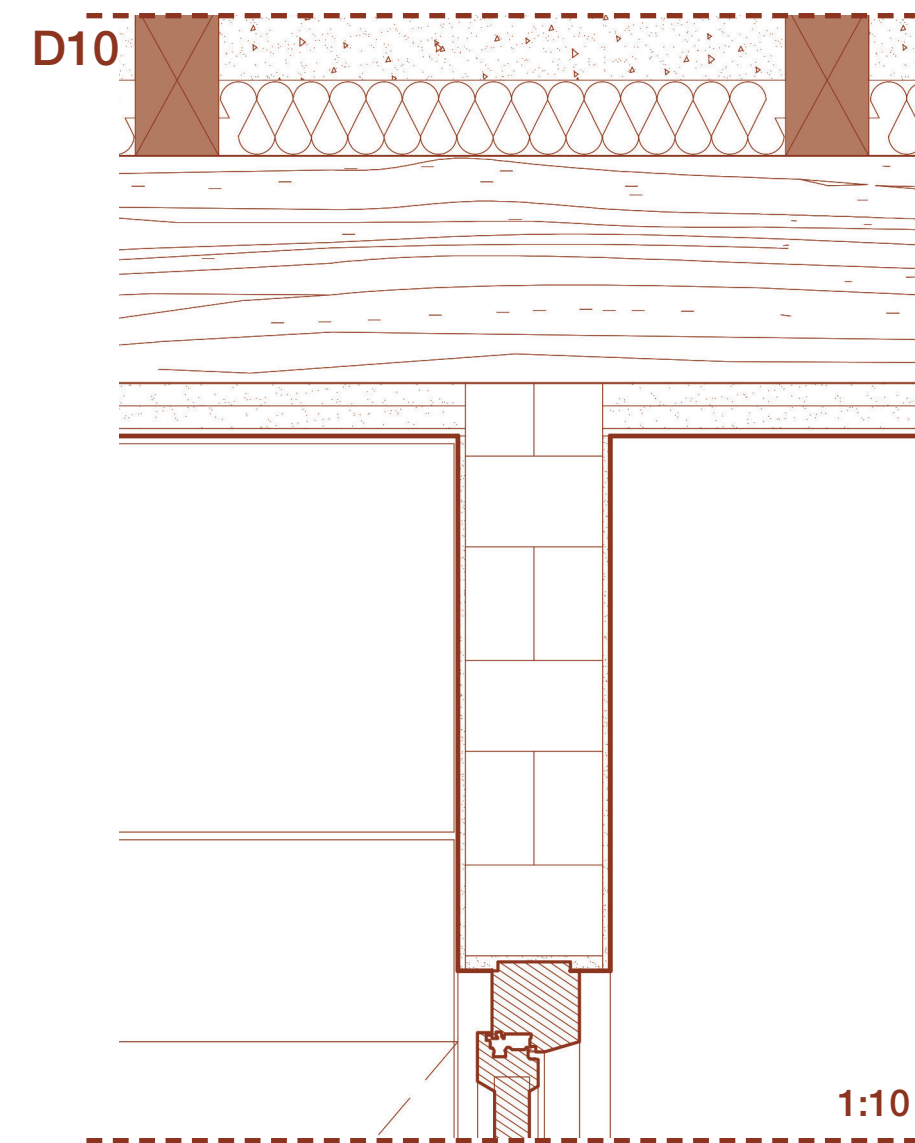
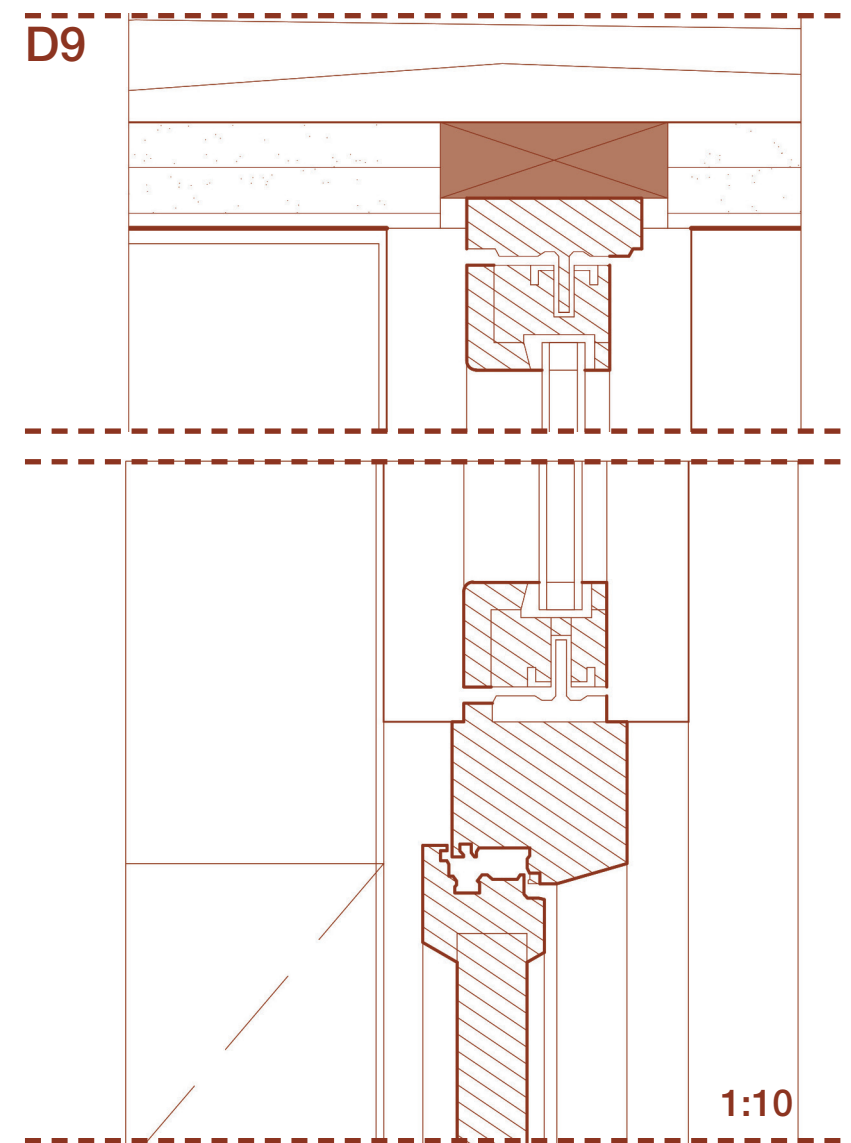
Prefabrication- design possibilities | Modularity





1. Wooden rail
2. Stone crown with 2% inclination +lime based binder+ In situ fabricated r.e.
3. Crushed volcanic gravel filling
4. Gutter for rain water collection
5. OSB board with waterproof membrane 2.5cm
6. Low fired mud tile covering 4cm
7. Damp-proof membrane
8. R.E. prefab panels
9. Cork insulation
10. Vapor membrane
11. CEB wall 20cm
12. Clay undercoat and finish plaster

D.Axo2. Roof hanging the extended beams of the balcony



Exploded axonometric of construction “ingrediedients”

